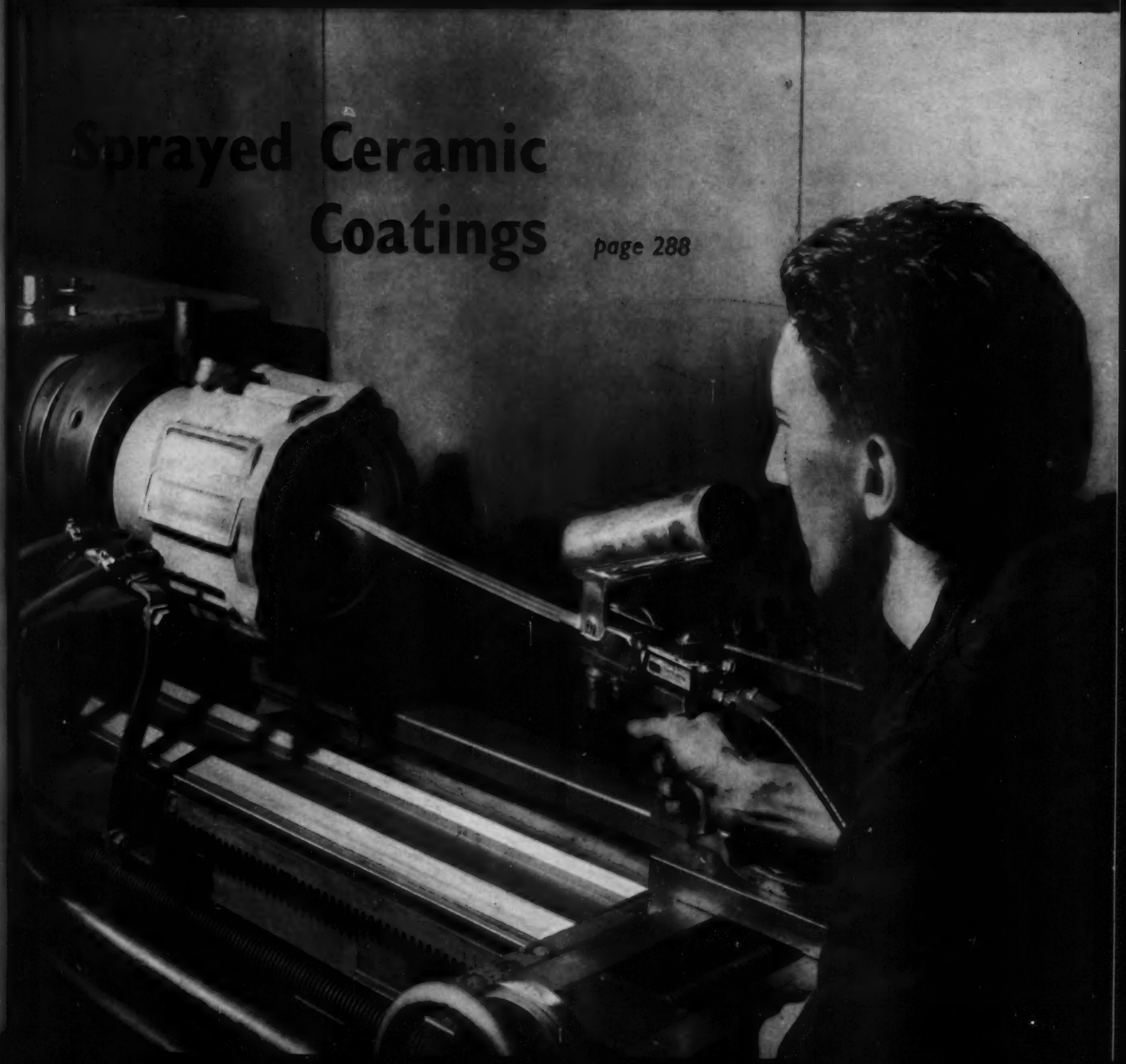
& Use of Materials, Components & Finishes in Engineering Design

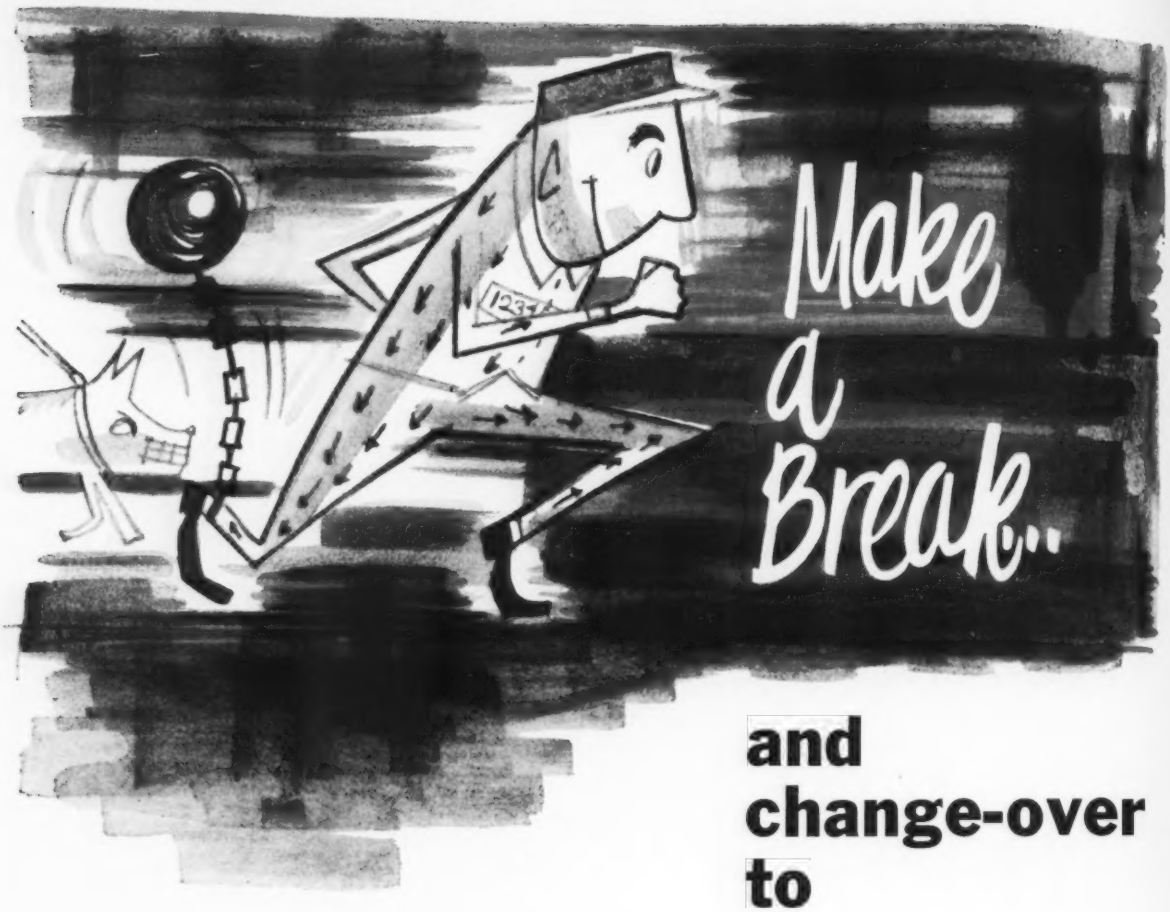
ngineering Materials and Design

MAY 1960

TWO SHILLINGS AND SIXPENCE



EMD 2632 for further information



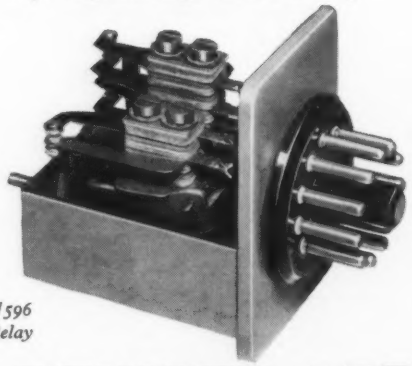
and change-over to

MAGNETIC DEVICES RELAYS

- ✳ Wide range
- ✳ Keen prices
- ✳ Speedy delivery

Magnetic Devices specialise in the production of many types of relay. The standard range includes enclosed, hermetically sealed, miniature, sub-miniature, plug-in, screw terminal and transistorised types; for A.C. and D.C. operation.

Special relays for prototype equipment can be supplied — consult our design engineers.



Series 590/596 Enclosed Relay

MAGNETIC DEVICES LIMITED

AID & ARB APPROVED

MAGNETIC DEVICES LTD

NEWMARKET · ENGLAND

Tel: Newmarket 3181 (5 lines) Grams: Magnetic Newmarket

P.4534

Engineering Materials and Design

★ *The Magazine for Engineering Designers*

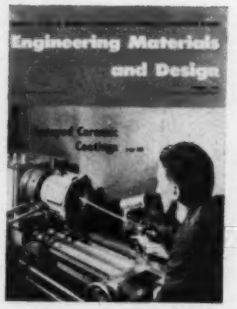
A HEYWOOD PUBLICATION

Vol. 3 No. 5 May 1960

EDITOR
H. R. Heap, B.Sc., A.M.I.E.E.

TECHNICAL EDITOR
R. D. Cullum, M.I.E.D., A.R.Ae.S., M.I.A.S.

ASSISTANT EDITORS
F. R. Terrell
P. Burton



COVER—Davey Paxman diesel cylinder liner being sprayed on the waterside with 0·010-in. ceramic alumina coating to prevent corrosion and cavitation, carried out at Dowding & Mills Ltd.

Published monthly by HEYWOOD & COMPANY LTD., Drury House, Russell Street, London, W.C.2 (Tel.: TEMple Bar 3422), on the 15th of the preceding month. Annual subscription 35s. sterling per annum ($5.25, U.S.A. and Canada) throughout the world. Single copies to order from all newsagents and bookstalls, 2s. 6d. each (by post from the publishers, 3s. 0d. each). BRANCH OFFICES: Royal Buildings, 2 Mosley Street, Manchester, 2, Tel.: Central 9935; Bayliss House, Hurst Street, Birmingham, Tel.: Midland 5786; 52 St. Enoch Square, Glasgow, Tel.: City 3492; 527 Madison Avenue, New York, 22, N.Y., Tel.: Plaza 9-1171.

© Heywood & Company Ltd., 1960
Must not be reproduced without written permission.

ISSUE AT A GLANCE

page

DESIGN OF ANTI-VIBRATION MOUNTINGS **268**
Advances in rubber technology and vibration insulation.
By **Kenneth L. Johnson, B.Sc., A.I.R.I.**

HOW SURFACE-ACTIVE AGENTS ARE USED TO CONTROL WATER EFFECTS **273**
Effect of water properties on materials used in design.
By **C. D. Moore** and **Maurice Bell.**

SPECIAL-PURPOSE ALLOYS FOR INSTRUMENTATION AND ELECTRONICS **280**
Electrical and magnetic properties of nickel alloys.
By **C. Gordon Smith, M.A., A.M.I.E.E.**

SPRAYED CERAMIC COATINGS **288**
Thermal and abrasion resistance with alumina or zirconia.
By **J. Alan Sheppard.**

NON-MECHANICAL METHODS OF JOINING METALS **291**
Soldering, brazing and welding techniques.
By **G. Fitzgerald-Lee, F.R.Econ.S., M.I.E.I., A.R.Ae.S.**

OTHER FEATURES

Bonding Problems of Alumina-base Cermets **272**
New Ideas in Design **277**
Designer's Notebook **285**
Problems in Design (Readers' Solutions) **286**
Niobium High-temperature Alloys **290**
Strength from Whiskers **300**

REGULAR FEATURES

Materials in the News ... **257**
Editorial **267**
Overseas Newsletter **305**
New Books **306**
New Materials and Components **313**
News of Industry **321**

CLASSIFIED ADVERTISEMENTS ... ... facing page **264**

Résumés

LA CÉRAMIQUE POSÉE AU PISTOLET

J. Alan Sheppard page 288

L'auteur décrit la technique et les avantages de la méthode du pistolet Thermo-Spray qui permet de recouvrir des articles de substances céramiques, principalement de l'oxyde d'aluminium ou de la zircone, assurant ainsi à l'article traité une forte résistance à la chaleur et à l'abrasion. Il choisit plusieurs exemples pour montrer comment les fabricants appliquent cette technique, avec succès, à leurs produits.

SUPPORTS ANTI-VIBRATOIRES

Kenneth L. Johnson page 268

L'article examine diverses méthodes pour combattre, au moyen de supports en caoutchouc, la vibration des machines et autres phénomènes analogues ; il décrit plusieurs façons de calculer le genre de support qui convient le mieux aux applications particulières.

ALLIAGES POUR USAGES SPÉCIAUX

C. Gordon Smith page 280

L'auteur étudie quelques-unes des applications les moins connues du nickel, dans les alliages et à l'état pur, en particulier dans la fabrication des instruments et des appareils électroniques pour lesquels ses propriétés électriques et magnétiques sont fort utiles.

L'EAU ET L'ACTION DES AGENTS TENSIO-ACTIFS

C. D. Moore et Maurice Bell page 273

Cet article a pour objet d'aider l'ingénieur à comprendre l'influence des propriétés de l'eau sur la performance, le dessin et la sélection des matériaux de construction, ainsi que l'action des agents tensio-actifs.

Kurzreferate

AUFGESPRITZTE KERAMIKBELÄGE

J. Alan Sheppard Seite 288

Der Artikel beschreibt den Einsatz und die Vorteile der Thermospritz pistole zum Aufbringen eines aufgespritzten Keramikbelags, gewöhnlich Aluminiumoxyd oder Zirkoniumoxyd, der einen hohen Wärme- und Abriebwiderstand verleiht. Ausgewählte Beispiele zeigen, wie Fabrikanten diese Methode erfolgreich auf ihre Fabrikate anwenden.

VIBRATIONSVERMINDERNDE AUFHÄNGUNGEN

Kenneth L. Johnson Seite 268

Der Verfasser bespricht Methoden zur Beseitigung von Machinenvibration und Lastproblemen durch Gummiabstützungen und beschreibt Mittel zur Berechnung des für einen gegebenen Zweck besten Aufhängungstyps.

SPEZIALLEGIERUNGEN

C. Gordon Smith Seite 280

Der Artikel bespricht weniger bekannten Anwendungen von Nickel als Legierungsmetall und als selbstständiger Baustoff, und betont besonders dessen Einsatz in der Instrumentierung und Elektronik, d.h., seine elektrischen und magnetischen Eigenschaften.

WASSER UND DER EINFLUSS VON OBERFLÄCHENAKTIVEN MITTELN

C. D. Moore und Maurice Bell Seite 273

Der Artikel hat den Zweck, dem Konstrukteur zu helfen, den Einfluss und die Eigenschaften von Wasser auf die Leistung, Konstruktion und Wahl von Baustoffen und die Einflüsse von oberflächenaktiven Mitteln zu verstehen.

Резюме

ОБЛИЦЕВАНИЕ КЕРАМИЧЕСКИМ ОПРЫСКИВАНИЕМ

Ж. Алан Шеппард стр. 288

Описываются техника и преимущества термо-пульверизатора при опрыскивании компонентов керамическими матерьялами — в частности окисью алюминия или окисью циркония для того, что-бы получить наивысшую степень сопротивления нагреву и абразии. Приводятся примеры успешного применения этого процесса различными фабрикантами.

АНТИ-ВИБРАЦИОННАЯ УСТАНОВКА

Кеннет Л. Джонсон стр. 268

статье обсуждаются методы предотвращения вибрации машин и других вызванных напряжением проблем, путем каучуковых монтажных частей. Описываются способы расчета типа установки, наиболее подходящей к данному процессу.

СПЛАВЫ СПЕЦИАЛЬНОГО НАЗНАЧЕНИЯ

С. Гордон Смит стр. 280

В статье обсуждается менее обычное применение никеля в качестве сплавочного вещества и в чистом виде. При этом особый упор делается на их использование в аппаратуре и в электронных приборах, т.е. их электрические и магнитные свойства.

ВОДА И ЭФФЕКТЫ ВЕЩЕСТВ С АКТИВНОЙ ПОВЕРХНОСТЬЮ

С. Д. Мур и Морис Белл стр. 273

Цель этой статьи помочь конструктору понять влияние свойств воды на повеление, технологию и выбор матерьялов для постройки, а также эффекты оказываемые на них веществами с активной поверхностью.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Canberra Uses the New Materials

THE LARGEST PASSENGER SHIP to be constructed in Great Britain since the *Queens*, the new P. & O.'s *Canberra* has many features in her design which are sufficiently unusual to be called revolutionary. Particularly is it noticeable that great use has been made of "new" materials, that is materials which are relatively new to shipbuilding. Designers must always try to provide the maximum amount of passenger accommodation within the restricted dimensions of the vessel, and one way of increasing the amount of accommodation is to replace steel with a lighter material for the superstructure. By using aluminium on the *Canberra* (over 1,000 tons of it) for a fully-welded superstructure it was found possible to incorporate an additional deck and the increased accommodation obtained more than offset the increased cost of aluminium.

Plastics feature largely in the ship's construction, and walls and ceilings throughout will be covered in either melamine-surfaced laminate or p.v.c. This will eliminate painting cabin interiors and is expected to show great savings in maintenance costs. Reinforced plastics, mainly the glass-polyester type, are used for the lifeboats as well as many interior fittings. Window linings, drawer linings and recesses for wash-basins use this material and a complete compartment containing shower and toilet is moulded from it for first-class accommodation. On the engineering side an attempt has been made to eliminate chemical treatment of boiler water by an ion-exchange technique using water obtained from a single distillation of sea-water.

High-temperature Hydraulic Fluids

HYDRAULIC SYSTEMS in airborne vehicles are dependent on the fluids used, which must retain their properties over an extreme range of temperatures, the upper limit being the most critical.

Compounds of particular interest for high-temperature application are those containing four phenyl groups, namely, the phenoxyphenyl ether. Like most of the others in this class of compounds, several isomers can exist, physically the difference in isomers being merely in structure: the only difference in properties is found in the melting point. The meta isomer not only exhibits a low melting point but super-cools and remains as a liquid below its normal freezing point (40 deg. C) to about —15 deg. C. (pour point). With this low pour point it is the only fluid now available, with potential for use at 550 deg C. which will remain liquid below room temperature. Recently, considerable work has been done in the development of a 550 deg. C. hydraulic system by Republic Aviation Corp. Bis (m-phenoxyphenyl) ether is being tested for use in this system and has been successfully run for many hours at 550 deg. C., and although decomposition begins to take place at 440 deg. C. the fluid remains usable for periods up to 10 hr.

It is essential that the bis (m-phenoxyphenyl) ether be of extreme high purity since it has been noted that certain trace impurities, not removed during manufacture, will cause the ether to crystallise at temperatures below 40 deg. C. A mixture of isomers recently produced, however, has shown excellent stability and has demonstrated no tendency to solidify even when seeded with crystals.

The lubrication ability of the fluid while not comparable to an oil of a mineral base is quite good, especially when compared to the silicone base fluids. In addition, this fluid has excellent nuclear radiation resistance, and this feature is becoming increasingly important as greater use of nuclear power is contemplated.

It is apparent from a curve of viscosity vs. temperature that bis (m-phenoxyphenyl) ether exhibits a sharp drop in viscosity with rise in temperature, but due to the absence of any form of improver, excellent shear stability resistance to breakdown due to mechanical working is realised.

Although the fluid possesses comparatively low flash and fire points, 240 and 300 deg. C. respectively, the spontaneous ignition temperature is high (600 deg. C.) allowing use of this fluid with safety to 550 deg. C. Bis (m-phenoxyphenyl) ether is also highly stable in oxidative atmospheres and can be used up to at least 320 deg. C. in an air atmosphere as long as no ignition source is present. It is hydrolytically stable, not exhibiting any reaction with water vapour, and decomposes above 450 deg. C. A drawback of the fluid is its relatively high vapour pressure, which can result in a considerable evaporation loss if not pressurised, and its present high cost.

Wire Explosions

IT IS REPORTED in Germany that copper and silver wires of about 0.1 mm. diameter have been very suddenly vaporised by use of a condenser discharge. A statement of the course of the explosion and the energy associated within the wire can be prepared from oscillograms of the current and voltage behaviour and optical observation of the light behaviour.

By measurement of the energy absorbed, the temperature reached in the explosion (over 50,000 deg. K.) can be estimated if the energy lost through radiation, shock waves, etc. is neglected. It is shown that the temperature in the interior of the wire can be considerably higher than on the surface. Expansion effects are believed to confine the electrical conductivity to the inner part of the wire where a most intense heating takes place. Furthermore, the energy in the interior cannot be carried away as rapidly (because of slow heat conductivity) as that on the surface since it is removed by radiation. Thus there results a rising temperature gradient, with increasing power density.

New Lamps for New Fittings

A RECENT STATEMENT by the Cable Makers Association was published in the February issue of *Electrical Supervisor*, the journal of the A.S.E.E., drawing attention to the fact that the physical size of modern incandescent lamps has been reduced, so that it is now possible to put a 100-watt lamp in an enclosed type fitting originally designed for a 60-watt lamp. This can give rise to extremely high temperatures at the lamp holder terminals and is liable to cause premature failure of the wire insulation or even the fitting itself. The three commonest wire insulations used today are natural rubber, p.v.c. and polythene; none of these should be used under such conditions that the maximum temperature rises above about 60-70 deg. C. An example is quoted of a ship-board lighting fitting designed for a 60-watt lamp which was incorrectly fitted with a 100-watt lamp and in tropical waters the rubber wire insulation was found to be 160 deg. C. This is probably an extreme case, but obviously calls for either a redesign of fitting or the use of silicone-insulated cable. Although there are clearly going to be serious problems in dealing with the replacement of lamps in existing installations, designers should have this matter brought to their attention and they should be warned to take care in making use of the higher light outputs from modern lamps by making sure that the safe temperatures of insulating and constructional materials are not exceeded.

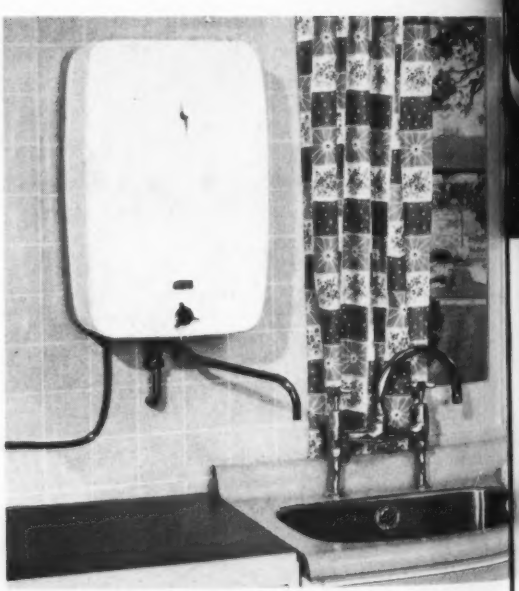
PICTURE NEWS
IN THE WORLD OF MATERIALS & DESIGN

ESCAPE CAPSULE

This crew seat (shown left) for the Convair B-58 supersonic bomber has been developed by Stanley Aviation Corp. to overcome need for restrictive protective gear in flight. After ejection from aircraft, the capsule would appear as shown above, equipped with floats. After encapsulation, and before ejection, the pilot is still able to fly the plane since the control stick is inside the capsule and essential instruments are visible.

THERMOELECTRICS IN ACTION

Thermoelectric generator was developed in the U.S.A. by Borg-Warner mainly to utilise waste energy of jet engine exhaust, but is now being produced commercially. Here it is shown supplying power for a transistor radio. The thermo-couples (top left) are being heated by a small bottle of L.P. gas.



PORCELAIN WATER HEATER

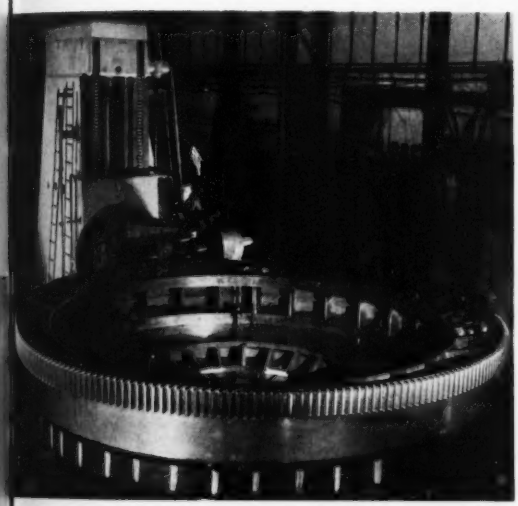
Unique feature claimed for this Main water heater is the use of porcelain in the container to obviate the risk of eventual corrosion. The apparatus plate is of stainless steel, and the container is lagged with mineral wool and aluminium foil to minimise heat loss.

HOVER VEHICLE

This ground effect hover vehicle was built by the Princeton University department of aero engineering for the U.S. Army to study fundamental stability control and performance characteristics.

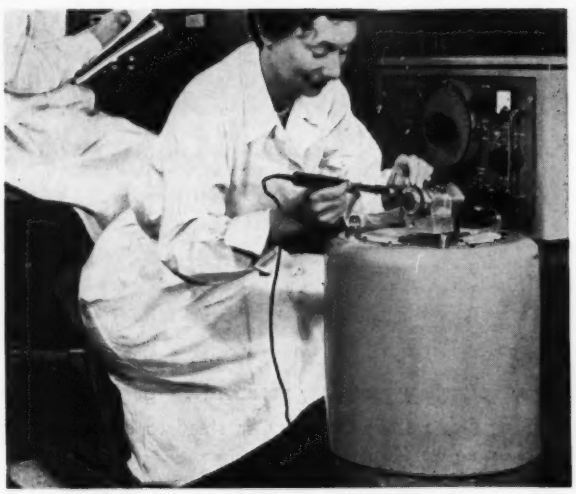
ALUMINIUM FOIL FOR COILS

These prototype coils in aluminium foil for a 50 kVA 11,000/433 volt three-phase oil-immersed distribution transformer were one of the exhibits featured on the Northern Aluminium Co. stand at the A.S.E.E. stand in London last month. The coils fit on a standard 50 kVA iron core and have a total weight of 69 lb. Their cost is said to be about half that of conventional coils.



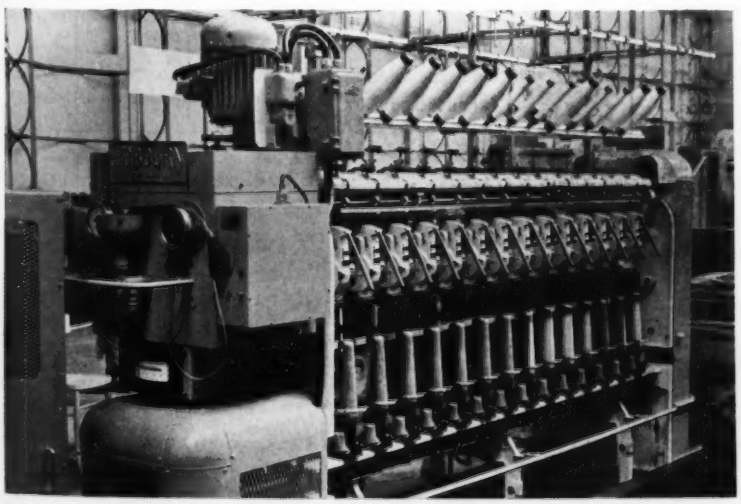
GIANT HOBBING

This machine at the David Brown Jackson division works at Salford is hobbing a combined path and ring gear. The machine's capacity has been increased from 16½ to 32 ft. diameter and as such is now the largest of its type in the U.K. and possibly in the world.



TESTING FOR VIBRATION

New vibrator type EMV 100A, made by E.M.I. Electronics, is said to have an exceptionally wide frequency range of 1-20,000 c/s. It is particularly suitable for testing at high "g" valves, components, instruments, parts of structures and other test objects.

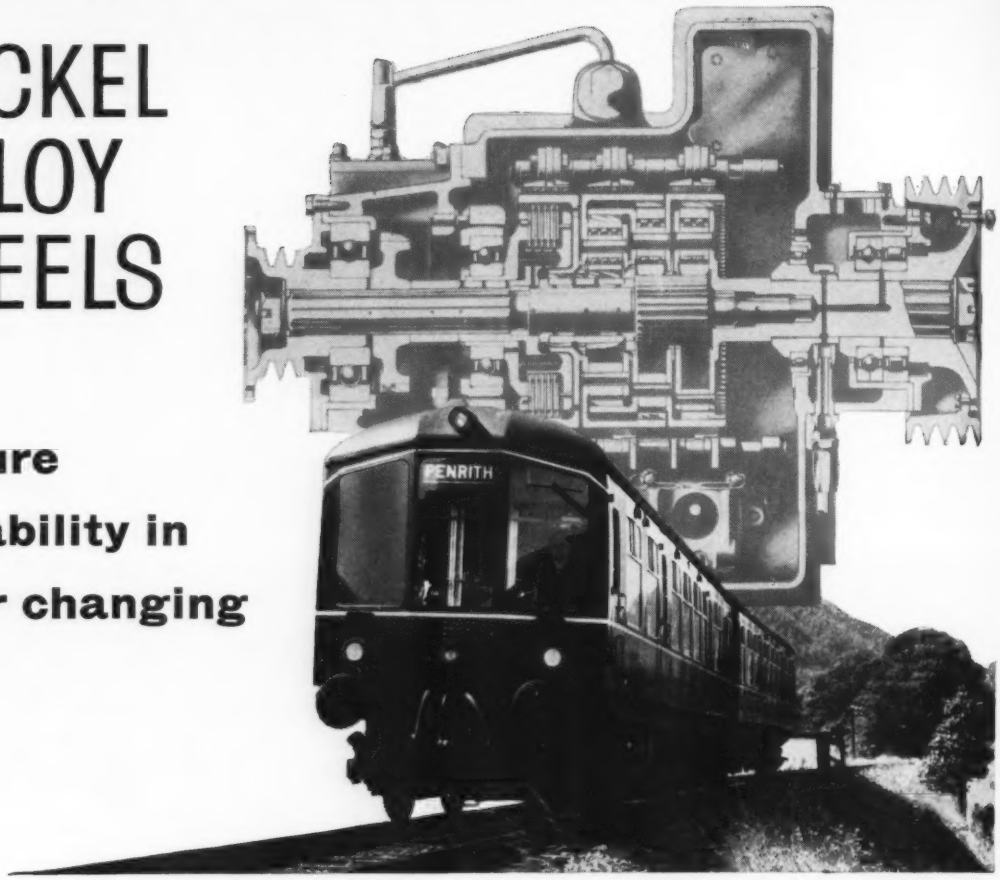


DESIGNING TEXTILE MACHINERY

Hobourn Agilon machine was one of several depicted as examples of originative development in textile machinery when the Council of Industrial Design recently held a conference on this subject in Manchester.

NICKEL ALLOY STEELS

ensure reliability in gear changing



The self-changing gear box, produced by Self-Changing Gears Ltd., Coventry, is standard on road, rail and water transport in many lands, and notably on London's buses.

This famous unit, in both its pre-selector and fully automatic versions, incorporates a range of nickel alloy steels. Although there is no direct mechanical operation of the gears in the normal way, heavy train, truck and bus operation inevitably imposes severe stresses upon the gears and to withstand these stresses most of the operating mechanism in the 'Wilson' box is made from nickel alloy steels, including the 3 per cent nickel-chromium-molybdenum EN 36 case-hardening steel.

TYPICAL CORE MECHANICAL PROPERTIES OF

EN36

SIZE	HEAT TREATMENT	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
1⅛" dia.	Oil quenched 780°C.	72·0	19	69
2⅛" dia.	Oil quenched 860°C.	62·7	19	67
	Oil quenched 780°C.			
3" dia.	Oil quenched 860°C.	59·7	22	72
	Oil quenched 780°C.			

The benefits to be gained from the more highly alloyed case-hardening nickel steels, such as EN 33, EN 34, EN 36 and EN 39 include ease of heat-treatment, minimisation of processing distortion, and general reliability.

Send for 'The Mechanical Properties of Nickel Alloy Steels' ▶

TGA 21/28

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, S.W.1

Computers—Large and Small

THERE APPEARS TO BE among engineers a widespread belief that computers are new, large and expensive items of equipment to be purchased only by large organisations with continuous accounting operations of such magnitude as to justify the cost of the equipment. Computers, however, are not new and they do not have to be large; these were two of the many interesting points discussed at the recent informal meeting organised by the Institution of Mechanical Engineers. However, computers are certainly new to many engineers who do not always appreciate what an immense power they can be for design, although when used wrongly—as with any powerful weapon—they could do great harm to the profession.

Naturally, it is the largest computers which get the most publicity, but it has also been shown that, provided the work loading is adequate (most large computers operate round the clock on a shift system), it is cheaper to use a very large fast computer than a smaller and slower one. That is why giants are continuing to be built.

The engineers' use for computers is twofold. First, he can speed up his designs or make them more thorough by carrying out calculations which he would otherwise not have time to complete. Second, he can use the computer technique to build automatic devices which open up many new possibilities in the manufacture or handling of goods. An instance has been quoted where calculations on pipe stresses which would have required three weeks by "hand" methods were carried out on a computer for £10-15; this example shows that there is scope for even small-scale problems. A computer was used for the drive system of the *Canberra* passenger ship where a thorough theoretical investigation was carried out on all shafting methods and propeller-excited resonances with the object of designing for minimum vibration under all conditions.

What of the future? Already there are signs of computer control to new problems. For what is believed to be the first time in any country, completely automatic forging of steel by pre-calculated programme has recently been successfully demonstrated by the British Iron and Steel Research Association. The flexibility of the E.M.I. Robo-Tug, an electrically-propelled automatic tug for towing trucks, threatens to supersede traditional conveyor systems, because its route and stopping programme can be altered at short notice and very cheaply. Not all firms will be able to justify the installation of computers but the larger users who own a computer sell time in the open market. Designers are often slow to use this excellent computer service because of a fear of having to wait in a queue. Many would rather not use these facilities if they cannot have a computer in their own office for their own exclusive use. The time is not far off when it may be possible to dial a problem over the national telephone system to a central computer service; already the G.P.O. are questioning users and potential users in an attempt to assess future demand for data transmission facilities, and giving a reminder of currently available services.

Thermoelectric Cold Box

THERMOELECTRIC REFRIGERATION has engaged the attention of engineers on both sides of the Atlantic for some time. News of what is claimed to be the world's first prototype thermoelectric cold box of commercial design has just been released by General Electric Co. Ltd. from their Wembley laboratories. The system is said to have the advantages of lightness, no moving or wearing parts, silent operation and the avoidance of the use of chemical refrigerants. It can operate directly from a battery or d.c. supply.

The box works on the principle of the Peltier effect developed to a practical stage by evolving efficient semiconductor thermocouples and forms of construction that provide adequate thermal isolation between the hot and cold sides of the junction.

Proceedings Ready Soon

A REPRINTED version of the proceedings of the recent Engineering Materials and Design Conference at Earls Court is being prepared and will be available shortly. This will include all papers delivered, together with a full report of the subsequent discussion at each session.

Copies, price two guineas each, may be ordered now from Heywood & Co. Ltd., Drury House, Russell Street, London, W.C.2.

Spraying sulfo-resinate of gold, mixed in pine oil, on to interior shell of Scout missile nose cone. The gold lining helps prevent heat from the missile's flight from damaging instrumentation inside the nose.

Gold in Engineering

GOLD, formerly used only for jewellery and finance, is helping today to overcome heat problems posed by space vehicles. This metal is gaining prominence in engineering because of its high heat reflectivity, relatively high melting point (1063 deg. C.), low spectral emissivity and excellent corrosion resistance. The fourth stage of the Chance Vought Scout rocket has its inner skin gold-coated to protect the scientific instruments from extreme heat caused by atmospheric friction, this plating being only 0.00001 in. thick and costing approximately 4s. 6d. per sq. ft to apply.

Because the parts of the rocket requiring gold plating are too large to use electrolytic and vapour deposition methods, a gold resinate, soluble in pine oil, is sprayed on the part to be coated, and baked in an oven at 190 deg. C. for 15 min. The coating turns to pure gold in a further hour-long bake at 380 deg. C.

Gold coatings also have another possible value for high performance aircraft, which radiate considerable infra-red energy. Some anti-aircraft weapons use infra-red seeking devices to locate aircraft targets. For this reason, it is desirable to have the emissivity at all wavelengths as low as possible to reduce the possibility of detection. By preventing structural heating through use of gold coatings on the internal skin structure or shroud, the heat radiated from the engine to an aircraft structure can be reduced substantially, lessening the danger of infra-red detection. A sizeable reduction in costly shroud weight may also be realised by gold coating in the engine area.

In the case of the Scout missile, the problem was to protect the payload of instruments contained in the fourth stage from excessive skin temperatures generated by high Mach number flight into space. By applying a highly emissive ceramic coating externally to the rocket's skin, the friction generated heat is radiated back into the atmosphere. On the inside, the low emissive gold coating was used to reduce heat radiation to the pay-load.

Another use for gold is on printed electrical circuits and contacts made from copper where the gold is deposited by ionic decomposition. The 0.000002 in. thick gold coating is lightweight, economical and continuous, and extends the storage life of printed circuits and improves soldability by increasing resistance to oxidation and tarnish.

unbreakable bonds

with High Impact Geon PVC

High Impact PVC cements made by Progressive Finishes Ltd. using High Impact Geon PVC.

Geon is a reg'd. trade mark

Cements based on High Impact Geon PVC provide a range of easy-to-use bonding agents which will still further extend the ever-increasing use of piping in High Impact Geon PVC. These cements produce a solvent weld . . . a perfect continuous bond possessing all the outstanding properties of the High Impact Geon PVC that it joins—great impact strength, resilience and resistance to rust, oils, grease and chemicals.

*Write today for Booklet No. **160** on High Impact Geon PVC.*

British Geon Ltd | A COMPANY IN THE DISTILLERS PLASTICS GROUP | Geon

SALES AND TECHNICAL SERVICE DEVONSHIRE HOUSE PICCADILLY LONDON W1 HYDE PARK 7321

Distillers Plastics Serve Everyman

Using Clad Steels

MODERN INDUSTRIAL PROCESSES, especially in the field of chemical engineering, the oil industry and nuclear engineering, provide an increasing demand for materials which will withstand the attack of a variety of corrosive media. Unfortunately, the available alloys which do provide this resistance to corrosion under these conditions are expensive and are not always available in large size plates. To overcome these problems, Colvilles Ltd. introduced a member called Colclad, consisting of a thin layer of cladding metal—nickel, stainless steel, Inconel or Monel—permanently bonded to a backing plate of plain carbon or low alloy steel.

Clad steels can undergo fabrication operations such as shearing, bending, flanging, forming or welding without buckling, cracking or separation of the layers. The petroleum and chemical industries are both large users of clad steels because of the large-sized equipment they require and the economy and long service life clad steels assured.

There are other advantages of clad steels over the homogeneous alloys as, for example, (a) the improved heat conductivity in comparison with solid stainless steel and Monel; (b) in profile cutting there is no need for expensive cutting machines, since the standard oxy-acetylene type of flame cutting equipment is completely satisfactory; and (c) the greater strength of clad steels in comparison with solid nickel and Monel allows a reduction for plate thickness, weight and material costs.

Another clad material with interesting possibilities is Feran, which is aluminium-clad steel, produced in Germany by Wickeder-Eisen-u Stahlwerk GmbH. This is said to make an excellent substitute for aluminium because its price is lower and the added strength given by the steel core means that thinner gauges can be used than for pure aluminium. Feran is about 10 per cent lighter than cold rolled steel, and is said to be more resistant to corrosion than tin-plate. The West German cycle industry is said to be using this material for wheel rims as well as mud-guards and it is also said to be used extensively by the German motor industry and for domestic appliances. Agents for the material in the U.K. are F. W. Kubach Ltd.

In the U.S.A. a new process that employs extrusion of clad metals was recently disclosed by the Battelle Memorial Institute. It is applicable to both simple and complex shapes and is said to have three main advantages: it permits close dimensional control over the cladded product; it permits a strong bond between core and cladding material; and the cladding does not have to be the same contour as the core.

In this method, the core material is fed through a hollow mandrel converging upon a die. The mandrel is housed inside a chamber containing rams that are used to extrude the cladding material, which is forced through ports located in the chamber between the terminal end of the mandrel and the die. Thus the core and the cladding material pass through the die simultaneously, and both are heated in the extrusion chamber. The process could evidently be operated on a continuous basis. Most of the work so far has involved aluminium-clad steel, but the process can also be used to clad aluminium on copper and nickel and alloys of these materials.

Glass-metal Composites

RESEARCH by the Owens-Corning Fiberglas Corp. into glass-metal composites is now in its fifth year and considerable progress has been made in conceiving and evaluating the properties and behaviour of various combinations of materials of acceptable strength/weight ratios suitable for service in the 800-1100 deg. C. range. A major effort has been directed to improving the characteristics by determining the variables affecting their behaviour. One investigation was concerned with the factors controlling the strength of single filaments in the operation of forming and coating them with molten metals, and in another investigation the physical properties of composite materials were examined in relation to the theories which have been evolved to explain or predict their behaviour.

Powder metallurgy techniques have been used involving nickel, copper, stainless steel, chromium and brass with "E" glass or fused silica fibres, both bare and aluminium-coated. Experiments were performed on the thermal expansion of metal-coated fibres and glass-metal composites, and efforts were made to correlate the results with theoretical predictions. The properties of glass-reinforced aluminium composites were compared with those of sintered aluminium powder (S.A.P.) with the object of determining if the mechanisms by which the matrix metal of each are reinforced, are the same or different. The results indicated that glass-aluminium composites had properties which were similar or superior to those of the S.A.P. materials, but that the mechanisms were not the same. Stress-strain diagrams of glass-metal composites were examined with the object of learning or explaining the role of each component in the strengthen mechanism. Matrix metals used were lead, zinc and aluminium alloys; five of the nine aluminium alloys were variously heat treated, and although marked differences were observed, none were of such a nature as to explain the behaviour of the individual components.

It was obvious that composites with strengths in the range 800-1100 deg. C. would require a glass of higher temperature endurance then "E" glass and for this reason a method of drawing fibres from fused silica was developed and attempts were made to coat the fibres at forming, with various metals. A few trials were made at vacuum injection, casting molten metal around the fibres, but copper and its alloys oxidise so rapidly that the method was impracticable. For this reason adaptations of conventional powder metallurgy techniques were developed in which fibres coated with metal powders were hot pressed in dies to form green compacts.

Due to the wide differences in the ultimate strengths found experimentally for glass-aluminium composites and the ultimate strengths as published for commercial alloys, it was decided to see what effect the casting system used in producing composites might have on the strength of the commercial alloys.

Future work will be directed to discern the effects of the glass and metal in producing the unique set of properties found for the composite materials, and will be an extension of the present work in prosecuting studies on both aluminium-coated fibres and composites at high temperatures. Specifically, fibre strengths and stress-strain behaviour of various composites at elevated temperatures will be examined.

International Drawings

ONE OF THE PROBLEMS being tackled by the Organisation for International Standardisation is the international standardisation of technical drawing practices, which should simplify the exchange or preparation of drawings. Twenty-two countries (including the U.K., Canada, the U.S.A. and the U.S.S.R.) are active members of a committee studying the question and sixteen more have observer status. The main purpose of the work (a special sub-committee will be holding its fourteenth meeting later this year) is to provide general rules for the size of drawings, methods of projection, scales and lines, lettering and title blocks, dimensioning and tolerancing, and surface roughness indications on drawings. Later work will study representation of screw threads welding, piping, springs and other components.

THE JUNE ISSUE

of Engineering Materials and Design will include the following main features:

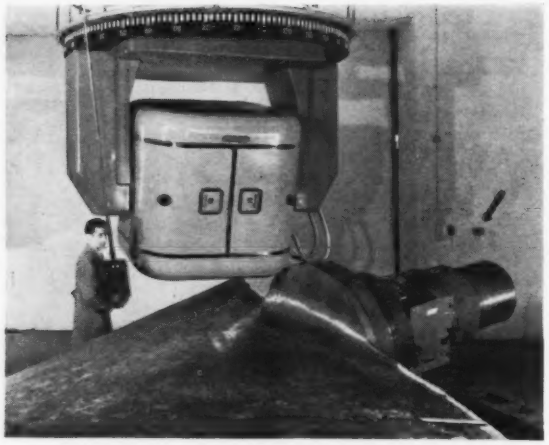
Fluid Cleaning and Filtration
Review of types and purposes of filtration units.

Fabrication of Clad Steels
Production and application of Monel, nickel, ferritic and austenitic stainless clad steels.

Inorganic Insulation
Compression and injection moulded glass-bonded mica.

Stretched Acrylic Sheet
How stretching can enhance properties of material.

Hydraulic Infinitely Variable Speed Transmissions
Survey of fluid-operated stepless transmission units.



Setting up the betatron for the examination of a Kaplan turbine blade.

Extruded Wood

AS WITH MOST MATERIALS, the efficient use of timber in engineering can only be accomplished by exploiting its own peculiar properties. At a recent lecture given before the Institute of Wood Science by Mr. P. O. Reece, director of the Timber Development Association, it was also suggested that in one sense timber had come to be regarded as a trade rather than an industry, which tended to obscure the virtue of timber in engineering. Recent developments indicated that designers were beginning to appreciate that for certain applications timber offers many advantages, particularly where specific stiffness is a criterion. Technological developments in timber have also enabled it to be considered as a candidate with other engineering materials, and among these the first real step was the development of plywood which enabled greater widths to be achieved with a uniformity in strength. Subsequent developments of glued laminations enabled shapes hitherto not economically possible to be produced in greater lengths and of a uniform quality. The advent of chipboard has opened new fields of applications and at present under development is a process of extruding sections which will enable more ultimate economies to be achieved.

To assist designers to foresee the possibilities of timber engineering, a series of information sheets and booklets are produced by the T.D.A., some of them dealing with structural hardwoods, standard glued laminations, and methods of calculating the bending strength of plywood. These booklets give practical information for the design engineer and it is most likely that with the greater appreciation of the properties of timber and the technical developments that are taking place, timber may find a new place of importance in engineering.

Betatron for Material Testing

FOR RADIOGRAPHING steel components and detecting faults in pieces 50-500 mm thick with a high degree of reliability, a 31-MeV materials-testing betatron plant has been installed by Brown Boveri at the works of George Fischer Ltd., in Switzerland.

The Swiss betatron operates at 31 MeV, the radiation which has been found to have almost the maximum possible penetrating power in iron or steel. Between the poles of an electromagnet lies an evacuated sealed tube in the form of a closed ring. The electromagnet is energised by 50 c/s a.c. from a transformer, the reactive magnetising current being supplied by a 1000-kVar bank of capacitors connected in parallel with the magnet-excitation windings. Shortly after the magnetic flux density has passed through zero, one of two electron guns injects electrons into the tube and, under the action of the magnetic guiding field, these circulate in an equilibrium orbit. Increasing the magnetic flux through the centre of the tube causes the electrons to be accelerated. With each circuit of the tube the electrons increase their energy by an average amount of 31 eV and at the end of the accelerating period of one-quarter of a cycle (1/200s for a 50 c/s supply) they have completed about one million circuits and therefore possess a kinetic energy of 31 MeV.

To convert this energy into penetrating gamma rays the orbit is expanded by means of a current impulse applied to the windings, so that the electrons strike one of the platinum targets and, being retarded, generate hard gamma rays which can be focused by optical or other means. So that a fault may produce a sharp image on a photographic film, even when the two are separated by some distance, a point source of radiation is necessary and the thicker the test object, the more important this becomes. In contrast to a radioactive cobalt source (which is an alternative method of radiographic examination of thick metal objects), the effective target area of less than 0.1×0.3 mm in the Brown Boveri betatron approximates closely to the ideal of a point.

While a radiograph is being taken, hydraulic rams grip the walls of the radiation room and hold the betatron steady. Components for testing are loaded on to a specially constructed railway wagon and conveyed through one of the two large doorways of the radiation room and on to a power-operated turntable.

Radiographs are taken on X-ray film sandwiched between 3 mm thickness of lead foil at the front (i.e. between the film and the test-object) and 1 mm at the back. Secondary electrons (Compton electrons and electron pairs) produced in the lead by the action of the gamma rays greatly accelerate the blackening of the film. At the same time, the lead absorbs secondary electrons originating in the test-object which would otherwise fog the film.

Exposure time for a very thick object can be reduced if two or even three films are exposed simultaneously. Each of the resulting radiographs will be of approximately the same density and quality, the density being weak on account of the reduced exposure time. If, however, they are viewed superimposed, the density is doubled or trebled and in this way they can be conveniently scrutinised. Exposure time depends on the target-to-film distance, the material and thickness of the test object, the primary intensity of the betatron radiation and the film quality.

Processing for Beryllium

ALTHOUGH THE IMPETUS given to beryllium has been mainly through missile and nuclear research programmes, it is evident that the material possesses characteristics which can usefully be employed in other industries provided the designer is able to interpret them correctly. Missiles and nuclear energy are unlikely to absorb the future output of beryllium originated by this programme and other applications must therefore be sought.

At first sight the cost may be regarded as prohibitive, but taken in conjunction with the material's advantageous modulus and low density, the cost may be comparable with conventional materials. Although much of the cost is in fabrication, a considerable part is due to the process of extraction, and here the programme initiated by the Imperial Smelting Co. could well lead to a reduction in cost. At present raw beryllium is imported, and this company is the first in the U.K. to process commercially the metal from the oxide, using the magnesium thermal reduction method. At a later date the operation will be extended to cover extraction from beryl ore.

To meet the stringent requirements of the U.K.A.E.A. the plant has been devised to ensure maximum purity of the metal at all stages, and considerable use has been made of plastics of various types for ducting, reaction vessels and storage containers. With the full co-operation of the Beryllium Corp. of America, it is to be hoped that British-produced beryllium will play a significant part in increasing the use of the metal in industry where its properties can be usefully exploited.

FOR FURTHER INFORMATION:—

Timber Development Association, 21 College Hill, London, E.C.4.
British Iron and Steel Research Association, 11 Park Lane, London, W.1.
E.M.I. Electronics Ltd., Hayes, Middlesex.
P. & O. Navigation Co., 122 Leadenhall Street, London, E.C.3.
Imperial Smelting Corp. Ltd., 37 Dover Street, London, W.1.
Cable Makers Association, High Holborn House, London, W.C.1.
Chance Vought Aircraft Inc., Dallas, Texas.
Owens-Corning Fiberglas Corp., 608 Madison Avenue, Toledo 3, Ohio.
Brown Boveri Ltd., 75 Victoria Street, London, S.W.1.
Republic Aviation Corp., Farmingdale, Long Island, New York.
Colvilles Ltd., 195 West George Street, Glasgow C.2.
F. W. Kubach Ltd., 12 Sylvan Road, London, S.E.19.
Battelle Memorial Institute, 24 Ryder Street, London, S.W.1.

DESIGN IN TEXTILE MACHINERY

OVER a year ago we suggested that a more lively attitude to the design of machine tools was overdue, but at the moment our thoughts are concerned with machinery for the textile industry which was the subject of a one-day conference recently organised by the Council of Industrial Design at Manchester. We came away from this conference with the feeling that this is another branch of engineering where the designer plays a vital part, but where some stimulation is needed.

The conference was aimed primarily at senior management of firms concerned with the manufacture of textile machinery with the object of drawing attention to the value of good design to the user and to propagate suggestions of ways in which trained industrial designers can help. Although it achieved these objects in an admirable manner, it disclosed a remarkable gap which appears to exist between maker and user. The point was made that the best designer is, in fact, the user and even if this may be a slight exaggeration it would seem wise to incorporate the users' ideas to a considerable extent. However, one of the difficulties which faces the machine manufacturer is that 50 per cent of the output of textile machinery is exported and British users do not appear to have precisely the same requirements as those overseas. The textile trade in this country reached its peak about 1914, but the fall in business since then has led to drastic reorganisation with the object of cheapening processes and reducing prices. Therefore, on the home market the textile machine manufacturer has to concentrate on providing equipment of minimum cost and maximum earning capacity almost to the exclusion of all other factors. For overseas markets these other factors, such as appearance and economy of maintenance, play a more important part and it is disturbing to find that foreign buyers have expressed surprise when they have found elegant designs in Britain.

Standards of appearance vary enormously in different countries, and the only way to keep up to date with current taste and trends is for the manufacturer and his designer to visit customers on site and listen to their views in their own surroundings. Mr. Paul Reilly, director of the C.o.I.D., said: "A firm that wants to project a clear and impressive picture of itself must do it in everything it handles. This ideal can be summed up in two words —design policy—and it follows that a policy of this importance must start at the top—at board level. But how many British companies yet have a director personally responsible for overseeing all these issues? In far too many, design decisions seem to be taken half-way down the ladder, or even lower."

It can be seen, therefore, that it is a waste of time to speculate on the detailed ways in which machinery design can be improved unless management itself is convinced that this is needed. On the other hand, exhortations to improve design and generalised statements on the dangers of bad design are not necessarily sufficient. The recent conference will have achieved a useful contribution even if it only highlights the importance of closer co-operation between manufacturer and user and particularly if it has publicised the differences between home and foreign markets.

However, if anything positive is to result it would seem to be necessary to follow up with a second conference directed at the designer and providing a detailed treatment on the technical aspects of the principles of good design. As an example, noise, although obviously one of the factors in the design of textile machinery, does not appear to have received the whole-hearted attention that it deserves. This applies not only to textile machinery but many other special purpose equipment, such as cable and lamp making machines. The use of new materials, either for the manufacture of gearing or reciprocating parts, as sound-deadening panels and for resilient mountings might well pay its way in terms of increased sales. Even if this was not manifest by an immediate effect on British users, we feel that overseas markets would benefit greatly, and once improved designs are available it is more than likely British users would take advantage of them.

The Editor

DESIGN OF ANTI-VIBRATION MOUNTINGS

Vibration is likely to occur whenever moving machinery is in use. This article discusses the types of rubber mounting units available and shows how to calculate which is most suitable for a given application

by KENNETH L. JOHNSON, B.Sc., A.I.R.I.*

THE general principles of vibration insulation have been widely known for some time. It has for long been recognised, however, that there have been certain deficiencies in the conventional application of these principles to rubber mountings, chiefly in respect of design for static loads and of effects of variations in frequency and temperature. Recent advances in rubber science have done much to remedy these deficiencies, making possible accurate prediction of performance in cases previously requiring service tests for their evaluation.

The simplest form of mounting consists of a rubber block, usually in the form of a cylinder or prism, bonded to metal plates on parallel faces. Such units are generally not employed in tension, because of the undesirable stress/strain characteristics in this mode. They may, however, be employed in compression or shear, and, so far as the static problem is concerned, there is nothing to choose between these modes, beyond convenience of manufacture and fitting in a particular application.

Four typical rubber units may be considered, as illustrated in Fig. 1. In each case the load is applied at the top and bottom surfaces, which are bonded to rigid plates.

STRESS/STRAIN CHARACTERISTICS — The stress/strain characteristics of these units in compression or shear are given by the following equations:

$$\text{In compression. } F = A.E\left(\lambda - \frac{1}{\lambda^2}\right)\left(\alpha + \beta\delta^2\right) \qquad (1)$$

$$\text{In shear, } F = A.G\,\frac{d}{h_0\left(1+\frac{h_0^2}{36k^2}\right)} \qquad (2)$$

In these equations,

F = applied force (lb.);
A = area of one bonded surface (sq. in.);
λ = compression ratio (see Fig. 2);
d = shear displacement (in.) (see Fig. 3);
E = Young's modulus (p.s.i.);
G = shear modulus (p.s.i.);
h_0 = initial height of unit (in.) (see Fig. 1);
α, β, δ, k = functions of shape of unit tabulated in Table 1.

This scheme of shape functions was developed by Payne,[1]

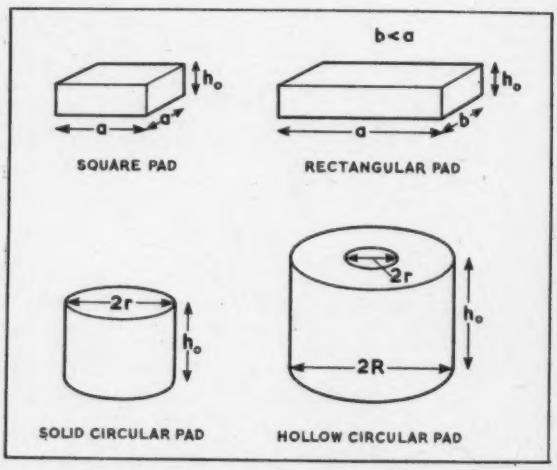


Fig. 1. Typical rubber anti-vibration units.

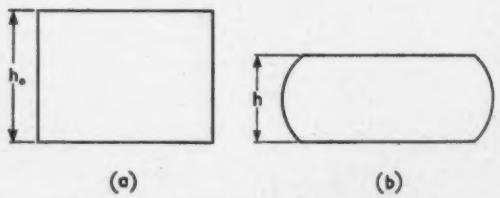


Fig. 2. Compressive deformation of bonded unit: (a) undeformed; (b) deformed. Compression ratio $\lambda = h/h_o$.

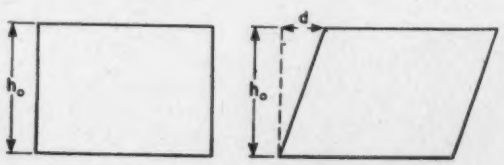


Fig. 3. Shearing deformation of bonded unit: (a) undeformed; (b) deformed.

* *Lecturer in physical testing, National College of Rubber Technology.*

who showed that it supersedes and includes the less comprehensive and less satisfactory schemes put forward by earlier workers. The factor distinguishing between cases 4 (a) and (b) in Table 1 is the extent to which the material can bulge into the central hole. The two cases really represent extremes, to one or other of which a practical design may approximate more or less closely, so that values of α and β intermediate between those tabulated may apply in particular cases.

DETERMINATION OF MODULUS—The quantities E and G in the above equations may be determined as material constants by carrying out tests on units of the above shapes and substituting the observations in the appropriate one of the above equations. A simpler and more accurate method, however, is that proposed by Jenkins and Cooper.[3] In this, a rubber cylinder is axially compressed between polished lubricated plates, and load/deformation readings are plotted. These are substituted in Equation 1 with $\alpha = 1$, $\beta = 0$. In this way E is determined; if Equation 2 is to be used, it is usually correct to write:

$$G = \frac{E}{3} \qquad (3)$$

Compression tests of this type have been stated to have advantages over the indentation hardness test for control of modulus (hardness) of rubber batches in production.[3] In practice, the test-piece used in a Goodrich Flexometer, namely a cylinder 1 in. high × 0.7 in. dia., is suitable for the test, and is often available in laboratories where such work is carried out. The only requirement of the lubricant is that it has no effect on the rubber. Silicone grease has been found satisfactory.

CREEP—The above equations apply strictly only at a single time of loading; that is to say, the deformation observed in practice under a steady load will be found gradually to change with time. This "creep" may be highly undesirable in a practical installation, producing dislocation of shafts and rigid electrical connections, etc.

Unfortunately, no general method for predicting creep effects at times longer than those available to direct experiment has yet been found. If such effects are to be taken into account, it is always necessary to carry out creep tests under conditions as close as possible to those of service. The results may be exhibited as a graph of the apparent value of modulus against time, or against logarithm of time. This is illustrated in Figs. 4-6. The logarithmic form of plot has two main advantages: in the first place, the instant at which load is applied, and during which observations are unavoidably inaccurate, is removed from the graph; and in the second place, behaviour at very long and very short times is easily displayed on the same graph.

The most important result of such tests, and one which is still not sufficiently widely appreciated, is that no limiting deformation for a rubber unit has ever been observed. Creep tests conducted for periods of eight[4] or ten[5] years give no indication of an end to the creep process. The importance of this in long-service applications is obvious.

DYNAMIC CONDITIONS—As soon as vibration is encountered, the situation becomes more complicated in several respects. These may be summarised briefly as: (1) change of modulus with deformation, (2) change of modulus with frequency, and (3) fatigue.

EFFECT OF STATIC DEFORMATION—The graph of compressive deformation (λ) against load (F) given by Equation 1 is not a straight line. Hence when a mounting supports a massive body, a small change in the deformation of the mounting produces a change in the reaction force

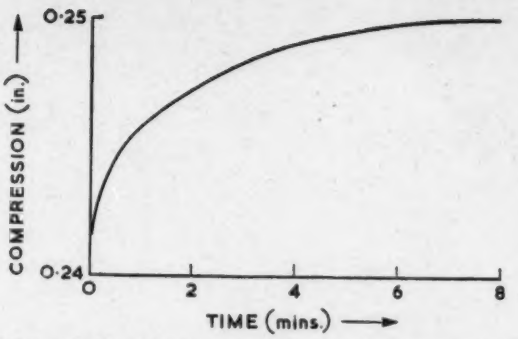


Fig. 4. Deformation/time graph for a rubber unit. Type 3. r = 0·3125 in. h_o = 0·375 in. F = 100 lb. (constant).[6]

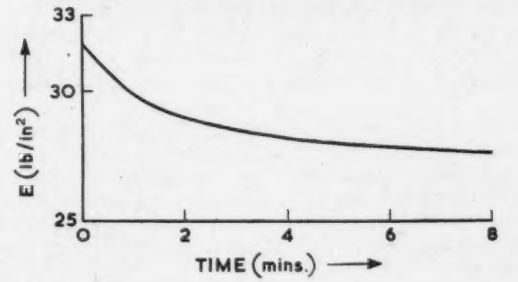


Fig. 5. Apparent modulus/time graph calculated from Fig. 4.

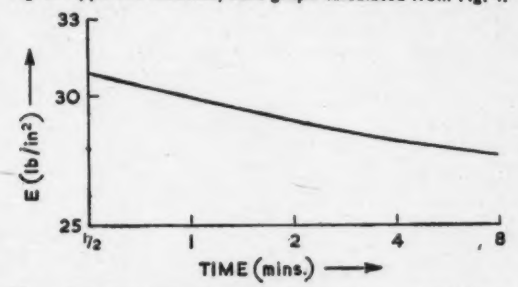


Fig. 6. Apparent modulus/log time graph calculated from Fig. 5.

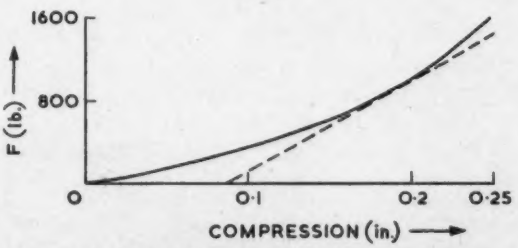


Fig. 7. Graph of load (F) against deformation, calculated from Equation 1, for a rubber unit, Type 1. a = 1 in. h_o = ½ in. E = 300 p.s.i. Effective static stiffness of unit in small deformations under dead load of 1,000 lb. = slope of broken line = 890 lb./in. Corresponding tangent modulus = 930 p.s.i.

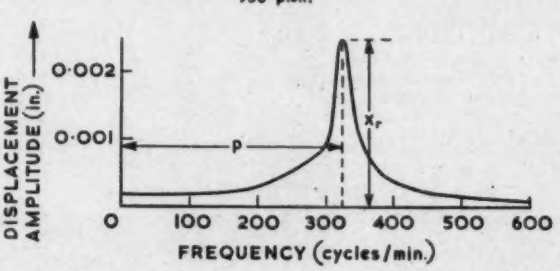


Fig. 8. **Right.** Displacement amplitude against exciting frequency (response curve) for any system of Fig. 9. m = 100 lb. s = 300 lb./in. b = 6 lb. sec./in.

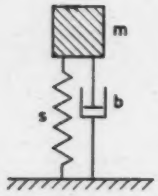


Fig. 9. Formal representation of a rubber unit in vibration.

TABLE 1. Shape functions (see Fig. 1)

Unit h_0	α	β	δ	k^2
1	1	0·525	$\frac{a}{2h_0}$	$\frac{a^2}{3}$
2	$\frac{1 + 0{\cdot}47\frac{b}{a}}{1{\cdot}37\left(1+\frac{b}{a}\right)}$	$\frac{1{\cdot}05}{1+\frac{b}{a}}$	$\frac{b}{2h_0}$	$\frac{a^2}{12}$ for shear parallel to a
3	1	0·413	$\frac{r}{h_0}$	$\frac{r^2}{4}$
4(a) R/r large	1	0·413	$\frac{R-r}{h_0}$	$\frac{R^2+r^2}{4}$
(b) R/r small	1·37	1·05	$\frac{R-r}{h_0}$	$\frac{R^2+r^2}{4}$

different from that produced by the same small deformation of the mounting from its unstressed condition. This necessitates use of the tangent modulus at the appropriate deformation, a procedure most conveniently carried out graphically, as illustrated in Fig. 7. With this modification, the load/deformation graph can still be regarded as a straight line as far as small changes in load or deformation are concerned, the value of effective modulus depending on the static load.

EFFECT OF SMALL VIBRATIONS—In vibratory applications, the rubber unit may often be represented by a spring and dashpot in parallel, as shown in Fig. 9. These have the parameters: s = stiffness of spring (lb./in.); b = viscous coefficient of dashpot (lb. sec./in.).

In vibrations of small amplitude, i.e. such that the load/deformation graph is approximately a straight line, these are related to material constants as follows:

$$s = \frac{A}{h_0} \cdot E_d \qquad (4)$$

$$b = \frac{A}{h_0} \cdot \eta \qquad (5)$$

where A, h_0 are as previously defined and:

E_d = dynamic modulus of material (p.s.i.);
η = normal viscosity of material (lb. sec./sq. in.)

These constants may be determined by vibration tests. E_d corresponds formally to the static compression modulus E, or shear modulus G, according to the mode of deformation. It is found, however, that E_d is not equal to the corresponding static figure, but is considerably larger. This has the important consequence that the stiffness of a rubber spring in vibration cannot be predicted from static tests alone. Vibration tests are indispensable for prediction of stiffness in vibration.

An important quantity relating to the above system is its undamped frequency, given in cycles per second by:

$$p = \frac{1}{2\pi}\sqrt{\frac{sg}{m}} \qquad (6)$$

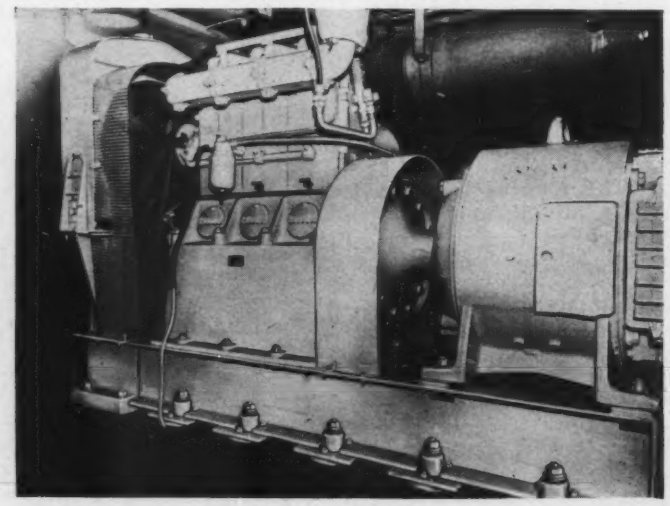
where g = acceleration of gravity (in./sec.²).

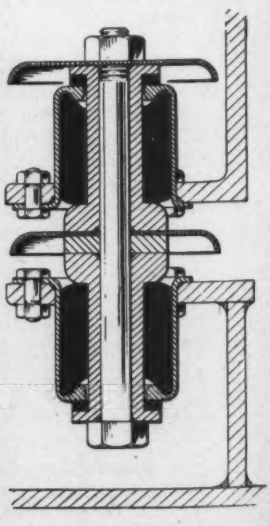
If the system be acted upon by a sinusoidally-varying force, the force is specified by its amplitude, F_m (lb.), and frequency f (c/s). If F_m be constant, the amplitude of vibration of the supported mass, m, is given by:

$$x_m = \frac{F_m}{\sqrt{(sg - 4\pi^2 mf^2)^2 + 4\pi^2 b^2 g^2 f^2}} \qquad (7)$$

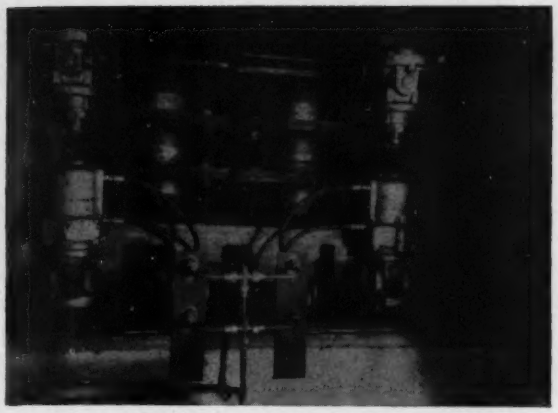
The graph of x_m against f is then as shown in Fig. 8. The critical feature of the graph is the peak, and the condition obtaining here is termed resonance. This occurs very nearly at the undamped frequency p given by Equation 6. The chief problem in designing a mounting for vibratory conditions is the securing of proper behaviour at and near resonance, and the most important requirements are as follows:

1. The amplitude at resonance, x_r, must be small, so as

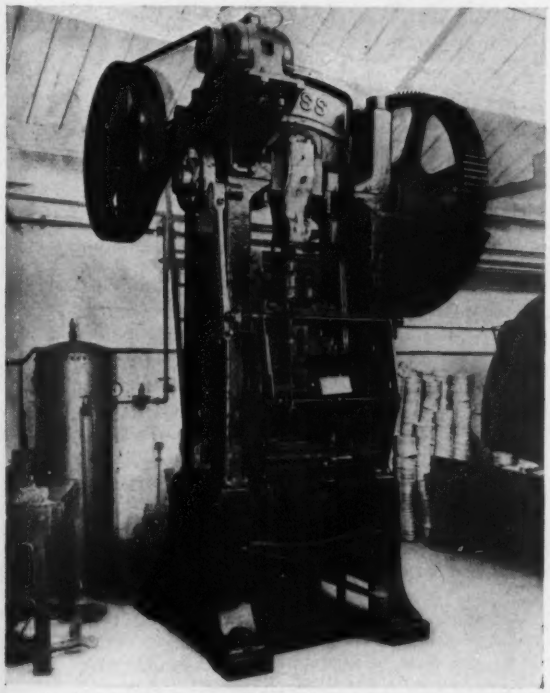




Diesel generator mounted on the ship *Saint Germain*. Diagram right shows Silentbloc double mountings fitted with oil shields used on this generator. In such applications, high-frequency elastic properties and fatigue resistance are the main considerations.



Double set of rubber compression mountings under drop stamp in works of Hawker Aircraft (Blackpool) Ltd. Each spring carries a load of 15 tons. Lockheed dampers provide near dead-beat damping. (Photo: J. H. A. Crockett.)



Bliss 15-ton press mounted on rubber compression mountings in works of John Glover Ltd. The mountings have eliminated high-frequency vibrations which previously shook nearby houses. (Photo: J. H. A. Crockett.)

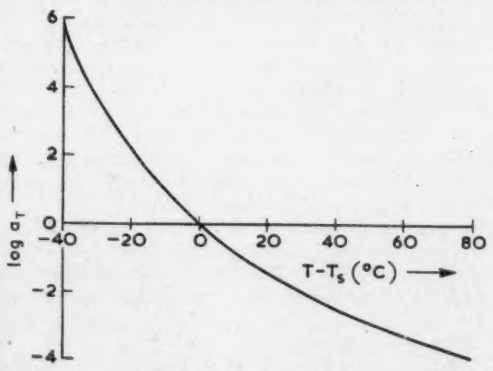


Fig. 10. Graph of a Ferry transformation (see Equation 9).

to avoid excessive stresses while the exciting frequency is in this region. This amplitude is given by:

$$x_r = \frac{F_m}{bp} \qquad (8)$$

so that this requirement calls for a large value of b, i.e. the use of a mounting material of high viscosity. This point is discussed further below.

2. The undamped frequency, p, must be well below the actual frequency, f, of the exciting force, so that the amplitude in steady vibration shall be small. From Equation 6 this requirement is seen to call for a small value of s, and from Equation 4 this is seen to entail either a small value of E_d or a small value of A/h_o. If pushed to extremes, this requirement thus calls for either a soft material, which may give adhesion trouble, or a tall, slender unit, which may be mechanically unstable. A more practical method of securing the required properties is to use rubber in shear: this has made possible the trend, evident for some years now, towards the use of squat, broad forms and comparatively hard materials (G in the region of 250 p.s.i.) for anti-vibration mountings.

Frequency and Temperature Variations—These two effects are equivalent, an increase in one corresponding to a decrease in the other. In practice, frequency effects can be directly investigated, since it is easy to design test apparatuses operating over wide ranges of frequency and covering all frequencies of importance in engineering applications. Temperature effects, however, are much more difficult to determine directly. The range of temperatures likely to be encountered has extended greatly in both directions in recent years: downwards, because of the increased activity in sub-zero climates, as in the various Antarctic explorations; and upwards, because of the high temperatures produced, both by motor units and by air friction, in jet- or rocket-powered flight. The construction of test apparatuses to function efficiently in either of these extreme ranges of temperature is often very difficult and always very expensive. Hence indirect methods are often preferable for investigating temperature effects.

The equivalence of frequency and temperature variations is expressed by the equation:

$$\log a_T = \frac{8{\cdot}86\,(T_s - T)}{101{\cdot}6 + T - T_s} \qquad (9)$$

where T_s = standard reference temperature for material (°C.).
T = temperature of test (°C.).
a_T = frequency ratio corresponding to change of temperature from T_s to T.

This is termed the Ferry transformation.[7]

Application of Ferry Transformation—To apply the above equation in the solution of a practical problem, it is necessary to know T_s, which is a characteristic of the material. Typical values are[8]:

Material	T_s (°C.)
Natural rubber (pure gum)	−21
Natural rubber with 50 parts HAF black	−20
Natural rubber with 20 parts ester softener	−33
GR.S	+3
"Arctic" GR.S	−16
Butyl rubber	−30
Thiokol RD	+33

Values corresponding to the above may be determined for other materials. The value T for the temperature at which performance is to be predicted may then be substituted in Equation 9, along with the appropriate value for T_s, and a value of a_T calculated. This is the factor by which the frequency at temperature T must be multiplied to give

the equivalent frequency at temperature T_s. A graph of log a_T against $T - T_s$ is given in Fig. 10.

As an example, a natural rubber black-loaded stock will be considered. Taking the value of −20 deg. C. for T_s from the above table, a room temperature of +20 deg. C. gives $T - T_s = 40$ deg. C. Equation 9, or Fig. 10, then gives log $a_T = -2{\cdot}503$ or $a_T = 0{\cdot}032$. The dynamic properties of such a stock at a frequency of 1,000 cycles/min. and a temperature of +20 deg. C. are then equivalent to those of the same stock at a frequency of 32 cycles/min. and a temperature of −20 deg. C.

The limitations on this treatment are that the above relationship has been found to hold only within a range of about 50 deg. C. on either side of T_s, and that, for strict accuracy, values should be corrected for thermal expansion or contraction. The second of these, however, is often of negligible practical importance. The above treatment has been found applicable to a wide range of high-polymeric materials.

OTHER FACTORS—The above survey includes the principal factors in the design of anti-vibration mountings for which precise mathematical theories have so far been developed. Other factors of importance exist whose effects cannot at present be quantitatively predicted in terms of material constants. These include the effects of previous vibration (the so-called "Mullins" or "history" effect) and of fatigue. A general conclusion which may be mentioned here is that fatigue is accelerated by temperature rise in the mounting, and hence by excessive heat generation in continuous vibration. Avoidance of this can be shown to entail a small value of b, the viscous coefficient of the mounting, which conflicts with the requirement of a small amplitude of vibration at resonance (see Equation 8). This is one of the oldest and most familiar dilemmas confronting the designer. Present practice generally resolves it in favour of the low-resonance-amplitude requirement, it being usually found possible to avert excessive heat build-up in other ways.

The formulæ given in this article provide all the essential bases for designing a mounting to carry a given load under given vibratory conditions, as far as initial performance goes. When such a mounting has been produced, effects such as those mentioned in this section may then safely be investigated by simulated service tests, in the knowledge that the chief design requirements have already been met.

REFERENCES

1. A. R. Payne, *R.A.B.R.M. Research Report 84.*
2. H. L. Jenkins and D. H. D. Cooper, *Proc. Rub. Tech. Conf.*, 1948, 214.
3. A. R. Payne, *Rubb. J. & Int. Plast.*, **134**, 984 (1958).
4. M. Mooney, W. E. Wolstenholme and D. S. Villars, *J. App. Phys.*, 1944, **15**, 324.
5. W. N. Keen, *India-Rubb. World.*, 1953, **128**, 351.
6. "Glossary of terms used in vibration and shock testing", B.S. 3015:1958.
7. M. L. Williams, R. F. Landel and J. D. Ferry, *J. Am. Chem. Soc.*, 1955, **77**, 3701.
8. Andre Rubber Co. Private communication.

BONDING PROBLEMS OF ALUMINA-BASE CERMETS

IT has been determined from earlier studies that a solid solution of Al_2O_3-Cr_2O_3 or Al_2O_3-NiO spinel-plus metal displayed evidence of good wetting, but difficulty had been encountered in producing compact specimens fired in either hydrogen or in vacuum. Further recent studies* have now been made after firing in a helium-hydrogen atmosphere. It was assumed that for sufficient bonding to occur to produce dense specimens some reduction of the secondary oxide to metal must take place, and that this metal would, in turn, alloy with the original metal and provide a better bond between the oxide and metal phases. The helium-hydrogen atmosphere used was a non-combustible mixture with the helium acting as a hydrogen diluent and carrier for the gaseous products of reduction.

The rate of firing was approximately 120 deg. C. per hr. to the soaking temperature at which the specimens were left for 4 hr. and allowed to cool with the furnace.

The compositions of oxide solid solutions and spinels combined with iron metal were calculated on a volume per cent basis and varied from a high to low metal content, which varied the secondary oxide and possible amount of metal formed for alloying with the iron. Weight change data were measured to determine quantitatively the amount of secondary oxide reduced, it being found that the weight changes did not vary strictly with temperature, indicating that the firing atmosphere was more critical than temperature.

The general effect of increasing the NiO content in the Al_2O_3-NiO spinel-plus iron compositions was to increase the shrinkage. When the metal content was decreased in these compositions, again the general effect was to increase the shrinkage occurring. When the shrinkage values for the Al_2O_3-Cr_2O_3 solid solution-plus iron were compared with those of the Al_2O_3-NiO spinel-plus iron at the same temperature, generally the spinel-plus iron exhibited lower shrinkage values. However, when the Al_2O_3-Cr_2O_3 solid solution and Al_2O_3-NiO spinel at equal absorptions were compared, very little difference in shrinkage was noted.

The overall effect on the modulus of elasticity of increasing Cr_2O_3 content was to lower the firing temperature required to produce the maximum modulus of elasticity for that composition. Nearly every composition exhibited maximum modulus of elasticity values nearly equal or slightly above those reported for pure iron (27×10^6). The Al_2O_3-NiO spinel-plus iron compositions produced slightly lower values of elasticity than Al_2O_3-Cr_2O_3 solid solutions-plus iron compositions of equal porosities. This would indicate that Ni was a slightly less effective bonding or alloying material than Cr with iron metal. Varying the metal content had no noticeable effect on the modulus of elasticity values in either Al_2O_3-Cr_2O_3 solid solution-plus iron, or the Al_2O_3-NiO spinel-plus iron compositions.

The net effect on the strength by increasing the Cr_2O_3 content of specimens of equal porosities was to decrease the modulus of rupture values. Very little difference in strength was found between Al_2O_3-Cr_2O_3 solid solutions-plus iron and Al_2O_3-NiO spinel-plus iron. The reduction of iron content did not have any significant effect except in compositions containing 50 and 25 per cent iron where a reduction of strength was measured.

The conclusions reached were that cermet compositions of Al_2O_3-Cr_2O_3 solid solutions-plus iron and Al_2O_3-NiO spinel-plus iron exhibited modulus of elasticity values equal to or higher than pure iron alone. Also, compositions of 70 per cent Al_2O_3 and 30 per cent Cr_2O_3 displayed tensile strengths at 1,000 deg. C. comparable to the tensile strengths of pure iron.

* W.A.D.C. Report T.R.45-173.

HOW SURFACE-ACTIVE AGENTS ARE USED TO CONTROL WATER EFFECTS

The physical properties of water may seriously interfere with an effect desired by a designer. This article is to help him understand their influence on other design factors, and how they may be controlled by surface-active agents

by C. D. MOORE and MAURICE BELL*

WATER is not physically a homogeneous system, because of the attraction exerted on the surface molecules by those in the body of the liquid. In order to establish an equilibrium between the liquid and its vapour, the surface molecules must be under unequal constraint, and this constraint is manifested in a surface tension. Surface tension is evidenced in practice by a "skin effect", and the ease with which this skin can be penetrated defines how quickly a liquid will wet and spread. The surface tension of a liquid decreases regularly over a moderate range with an increase of temperature, and tends to deviate more, and becomes immeasurably small, a few degrees below its critical temperature. The reason for change in surface tension on the solution of a product in a liquid, or by mixing two liquids, was elucidated and characterised mathematically by Gibbs, who showed that substances which lower the surface tension in solution concentrate at the surface, while those which increase tension concentrate in the bulk of the solution.

A small amount of substance that migrates to and concentrates at the surface will reduce surface tension very considerably, whereas an increase in surface tension can only be accomplished by preferential concentration through the whole bulk short of the surface layer; this will explain why no substance yet known will increase surface tension by more than a few dynes/cm. even at high concentration.

When a new surface is formed, time is required to re-establish the equilibrium between the bulk and surface layer; this may take as little as 0·1 sec. in the case of a surface-active agent, or up to many days with a solution of a colloid. The term "surface-active agent" generally implies substances that reduce surface tension to a low figure both rapidly and in low concentration, but it must clearly be understood that all products dissolved in a liquid alter the surface characteristics; the question is one of degree. Practical operations involve both liquid-liquid and liquid-solid interfaces; the interfacial tension thus becomes important.

A practical means of assessing a tendency to wet and spread is by observation of the contact angle, which is the angle of contact between a drop of liquid and the surface on which it is resting. If a liquid is to spread on the surface of another liquid or a solid, there must be a reduction in the contact angle, and if the contact angle is zero, complete wetting will result.

* Glovers (Chemicals) Ltd.

Structure and Uses of Surface-active Agents

All surface-active agents, irrespective of type or class, have one feature in common: their molecular structure always contains a long fatty chain attached to a polar or similar head (shown diagrammatically in Fig. 1), which confers water solubility on the whole. The structure of sodium dodecyl sulphuric ester (Fig. 2), a common surface-active agent, exemplifies the above relationship. The long fatty chain is the portion up to the oxygen group, and the remainder is the sulphuric ester portion; ionisation of this part confers water solubility. It will be noticed that the structure carrying the long fatty chain is marked with a negative sign, and that of the sodium ion with a positive, indicating the state of the electrical charge on the portions of the molecule. Another surface-active agent, dodecyl trimethyl ammonium bromide (Fig. 3), indicates how the same general type of structure may appertain, but with the electrical charges reversed.

Because of the peculiar balance in the structure of all surface-active agents, i.e., the ratio of hydrophilic (water attracting) to lipophilic (oil attracting, water insoluble) portions there is a tendency for their molecules to try to "escape" from solution because of the enormous internal pressure of water exerted upon the fatty portion. This tendency to escape manifests itself by the molecule preferentially accumulating at the surface (see Fig. 4) and hence reducing the surface tension. The tendency to escape is evidenced further in that the molecules which cannot accumulate at the surface tend to form what is known as micelles. These are agglomerations of molecules which align themselves in such a manner that their fatty chains are towards the centre of the configuration (see Fig. 5), with their polar heads lying outwards towards the aqueous phase.

The balance between the hydrophilic and lipophilic sections of the molecule is described as the hydrophile/lipophile balance of the surface-active agent, a high figure indicating a high affinity for and solubility in water and a low one the reverse, i.e., high solubility in organic liquids and a low solubility in water. The hydrophile/lipophile figure (generally shortened to HLB value) of an agent is an extremely useful guide to performance, and reputable manufacturers of surface-active agents can usually give an indication of the figure for any of their products.

WETTING, SPREADING AND DETERGENCY—The most pronounced effect brought about by the addition of small quan-

tities of surface-active agents to water is a lowering of the surface and interfacial tensions which is observable in the fact that the water wets better, spreads more easily and possesses detergent properties. All the water-soluble surface-active agents have this effect in some measure, but in any series a point of maximum efficiency in the lowering of surface tension is to be found in those compounds whose bases contain a 10-12 carbon atom chain. Above and below this chain length a falling off in wetting power is observed, so careful selection is necessary for optimum results. The comparative wetting power of various surface-active agent solutions can be assessed by observation of the time required for wetting particles of, say, carbon black, or comparing the time required for canvas discs or hanks of cotton to sink in the solutions. In practice, it is often possible to carry out tests on the actual material which it is required to wet and this is obviously advantageous. Metal pickling and the cleaning of metals prior to plating depend upon the wetting power and detergent properties of a surface-active agent solution, and at different times all types of surface-active agents have been suggested for this purpose. In pickling operations involving the use of strong acids, wetting agents are often salted out, but recent work in the authors' laboratories has shown that non-ionic surface-active agents below the normal chain length for optimum wetting in purely aqueous solutions, and even insoluble in water alone, are both soluble and very effective wetting agents in strong mineral acids.

Increased wetting power is a desirable feature in electroplating solutions, not only for ensuring intimate contact between the solutions and the metal, but also to help obviate "drag-out" loss. Surface-active agents of the anionic class have been used for this purpose, but other types are suitable, provided they are soluble in and miscible with the plating solutions.

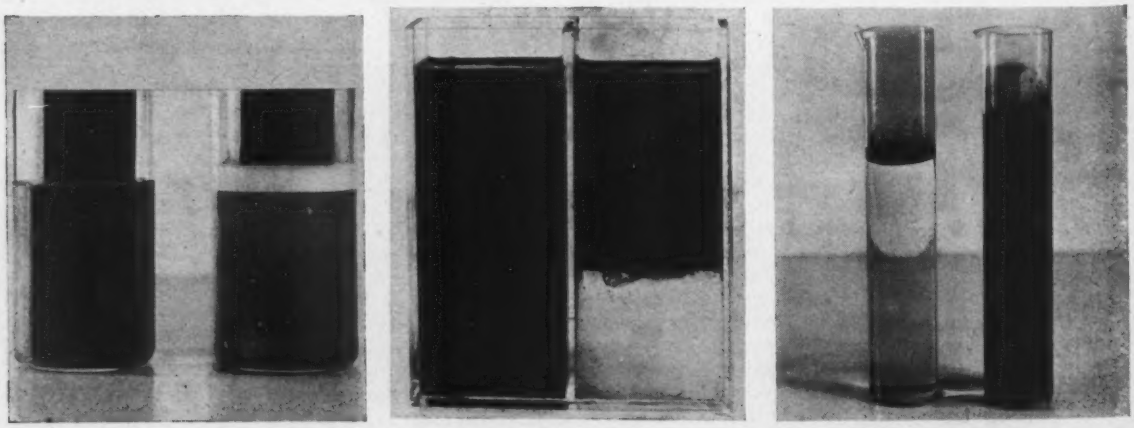
The damping of dusts formed in grinding operations to prevent nuisance, and sometimes to reduce explosion risks, is an inefficient operation using ordinary water sprays, but the addition to the water of a non-ionic wetting agent produces a very marked increase in efficiency even with concentrations of wetting agent as low as 0·005 per cent.

The point that has been made earlier about the time lag in re-establishing equilibrium whenever a new surface is formed in a surface-active agent solution is of paramount importance in the wetting of gases. Scrubbers and washers designed to remove dust and fumes from the discharge gases produced in various industries, or to wash boiler flue gases to comply with smoke abatement laws, often involve passing the gases, finely divided, through water in a high state of agitation. In another type of apparatus the gases are subjected to sprays of water as they ascend a vertical chamber. Surface-active agents vastly increase the chances of success of either type, but for maximum efficiency the apparatus must, of course, be designed to take into consideration the time lag. A bubble of gas entering the solution in a scrubber is presenting a new surface, and it is quite possible for it to pass through an improperly-designed scrubber so rapidly that there is no chance of equilibrium being established, and hence the solid particles encased by the bubble emerge completely unwetted. The best surface-active agent in the world will not cure this problem by itself, if this fact is not borne in mind in the design of such scrubbers and a sufficient time factor allowed. A further point with apparatus of this type is that the gases may contain a wide variety of solids of different chemical and physical properties, and it is unlikely that any single surface-active agent will bring about complete wetting of them all. Here is a case for two or more chambers to the scrubber connected in series and containing surface-active agents of different HLB values and even, possibly, with different charges.

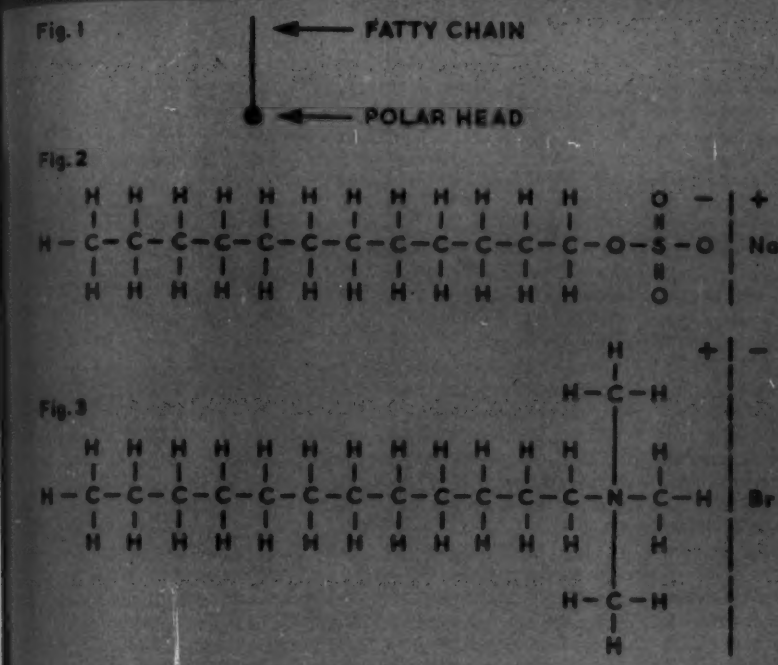
Emulsification and Demulsification

Another way in which the lowering of interfacial tensions by surface-active agents is made use of is in the formation of emulsions. Emulsions are intimate mixtures of two liquids which are normally very nearly, or completely, immiscible, and the function of the surface-active or emulsifying agent is to form an adsorbed film at the oil/water interface, thereby lowering the interfacial tension between the dispersed and continuous phases, and at the same time providing a protective adsorbed film. In practice, one phase is almost invariably water and the other an oily material and, depending upon which of these two is the dispersed phase, the emulsion is designated oil-in-water (O/W) or water-in-oil (W/O). The type of emulsion produced depends upon whether the emulsifying agent is preferentially water adsorbed, or oil adsorbed, and also upon the phase volume ratio. The most stable emulsions are produced where the dispersed phase accounts for 40-60 per cent of the whole, and if the volume of the dispersed phase is increased the emulsion becomes increasingly unstable. When the dispersed phase becomes greater than 75 per cent of the whole, the tendency for the emulsion to invert is very pronounced. Emulsions are, of course, a particular type of suspension and have the general characteristics of suspensions.

Emulsions of paraffinic-type oils are used as soluble cutting fluids to provide lubrication and cooling in a great many machining operations. Surface-active agents of the



Left. Effect on pieces of iron of acid in a pickling bath with and without a suitable surface-active agent. The right-hand cell (with the agent) shows vigorous evolution of gas. The photograph was taken 5 min. after immersion in each case. **Centre.** Effect of Fomescol on a fuel oil emulsion containing 40 per cent of water. **Right.** In two cylinders of water, oily flue dust which passes a conventional scrubber was sprinkled. In the left-hand cyclinder, containing water only, the wetting was obviously negligible after 24 hr. In the right-hand cylinder the oily carbon began to sink immediately, and the effect after 5 min. is illustrated.



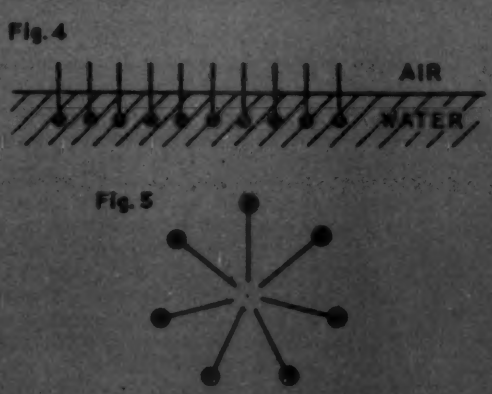


Fig. 1. Molecular structure of surface-active agents.

Fig. 2. Structure of sodium dodecyl sulphuric ester, a common surface-active agent.

Fig. 3. Dodecyl trimethyl ammonium bromide, another surface-active agent.

Fig. 4. How surface-active agents accumulate at the surface.

Fig. 5. Molecules unable to accumulate at the surface tend to form micelles, with the fatty chains aligned towards the centre.

sulphated or sulphonated type and alkylolamides are used for this purpose, and are added to the oil in sufficient proportions so that the oil will form stable emulsions immediately on addition to water. Products for use in the emulsion degreasing of metals are very similar, but contain proportions of other solvents necessitating the use of surface-active agents of slightly different HLB value. Emulsions of wetting agents, organic solvents and kerosene are used for the *in situ* removal of the impurities which build up on the compressor components of jet aircraft engines by passing the emulsion into the air intakes while idling; an emulsifying agent of the non-ionic type which combines good detergent properties is indicated for this purpose.

Buffing and polishing compositions can be formulated to include emulsifying agents to render the grease binder self-emulsifiable and thus readily removable by washing with water. The type of grease binder used will determine the HLB value of the emulsifying agent, but, in general, the non-ionic type has been found of value.

The mechanism of demulsification or the breaking into two distinct layers of stable emulsions is not as clear as that of emulsification. Even apart from the various mechanical or chemical methods by which emulsions can be broken, the methods involving the use of surface-active agents differ widely in mode of action. For instance, the surface-active demulsifying agent may tend to form an emulsion of the opposite type to that already present, and at a certain stage a point of minimum stability is reached when the emulsion will break. The surface-active additive may remove the emulsifying agent from its sphere of action either by double decomposition as when, say, cationics are added to anionic emulsions; or by shifting the HLB value to such an extent that the emulsifying agent becomes either too hydrophilic or too lipophilic to support the emulsion. Surface-active agents of every type and class have been used for demulsification for the very reason that the agents responsible for emulsion formation are so diverse and complex. The demulsification of fuel-oil emulsions, where perhaps the chief difficulty in this connection is encountered, was until recently only accomplished by using a variety of demulsifying agents each of which was specific for one type of emulsion only. Recent work has produced a new demulsifying agent of the non-ionic type which represents a great advance in that it is non-specific in its action and is effective for the general range of fuel-oil emulsions. Details of this product (called Fomescol) may be found elsewhere.[1]

Foaming and Anti-foaming

Just as emulsions are dispersions of one liquid in another liquid, foams can be regarded as systems in which a gas is dispersed in a liquid. Foam can be produced by introducing a gas, usually air, beneath the surface of the liquid or, as usually happens in practice, by disturbing the surface of the liquid to such an extent that it encloses air. Although foams are often produced in processes where surface-active agents are absent, and indeed without any lowering of surface tension, the formation of stable foams is facilitated by the use of surface-active agents and usually dependent upon a lowering of surface tension. In any series of surface-active agents, then, the capacity to produce foam is at a peak round about the region which gives maximum wetting, but between one series and another vastly different foaming properties may be observed; a good wetter in one series may produce copious foam while its counterpart in another series may be poor in this respect. Foaming is not a prerequisite of detergency; many very efficient detergents do not foam to any high degree, but there are operations which make use of a surface-active agent's capacity to produce foam irrespective of any wetting or detergency value the agent might have.

In the separation of valuable metal-bearing minerals by the process known as ore flotation, foams are utilised, and the mineral particles are caused either to become attached to air bubbles and floated off from the residues or to become suspended in the liquid while the residues are removed in the foam. Fire extinguishers often operate by foam formation; in this case the foam is acting as a blanket and preventing the removal of the products of combustion. High-foaming surface-active agents are used for making porous or foamed concrete by the entrainment of quantities of air. They have also been put to good use as additives to water-soluble waxes which are used for bonding and to give temporary

support during machining operations. On completion of the operation, it is necessary to remove all traces of the supporting wax by washing with hot water, and with a wax containing a foaming additive the complete removal of the wax is evidenced by the absence of foaming.

There are, unfortunately, many more operations where foam formation is a nuisance than there are of the kind where foam is desirable both in engineering and other trades, and the reverse phenomenon, anti-foaming is of great importance. Foams may be broken chemically by the interaction of an additive with the causative agent; mechanically, by replacing the foaming surface with a non-foaming one or by the use of certain types of surface-active agents, and it is this latter method which concerns us here. To be an efficient anti-foam a surface-active agent should be only very slightly soluble in the foaming medium, and yet have the power to spread rapidly upon the foaming surface and thereby effect the necessary changes in surface tension around individual bubbles so that the bubbles either burst or coalesce to form larger, more unstable bubbles. In general, surface-active agents of very low HLB values, particularly of the non-ionic type, are of most value as anti-foaming agents.

Foaming in boiler water is a cause of "priming" or the "carry over" of liquid into the steam lines. It can be attributed partly to the construction of the boiler, but mostly to impurities present in the water. Factors in boiler design which are said to influence foam formation include the location of steam outlets, the amount of vapour space above the boiling liquid, and the rate of evaporation; but impurities in the water are the main cause of the trouble, and the one which is amenable to anti-foaming agents. The types of surface-active agents most effective for this purpose are the low HLB non-ionics and polyglycols and particuly certain agents of the polyamide type; they are fed in the form of emulsions, or dispersions, into the feed water by standard proportioning devices. The use of anti-foam in boiler water helps to reduce the cost of steam generation by permitting the carrying of higher proportions of dissolved solids and by enabling efficient steam generation where high quality feed waters are unavailable.

Many other industries have foaming problems; sugar beet extraction, glue manufacture and paper-making all include processes where anti-foaming agents are necessary, and one practical difficulty is in getting the anti-foam to the right place, in the correct concentration at the right time. There seems to be a need for the design of suitable metering devices to control the drip feed or spray application of dispersed anti-foaming agents.

Suspension and Sedimentation

Suspensions are systems in which a solid is finely dispersed in a liquid, and surface-active agents assist in preventing sedimentation by influencing one or more of the various conditions on which suspension stability depends. Suspended particles have surfaces at different electrical potential from that of the surrounding liquid and surface-active agents may, upor adsorption, increase this potential difference and improve the stability of the suspension. Surface-active agents may alter one or more of the factors in Stokes' law, which relates the velocity of sedimentation of suspended particles to the viscosity of the suspending medium, the radius of the particles and the density difference between the particles and the suspending medium. Moderately hydrophilic surface-active agents are usually good dispersants for solid particles and, as is evident they are particularly so if they also produce an increase in viscosity in the liquid phase.

Surface-active agents may also bring about the reverse effect, i.e., increase the rate of sedimentation and destroy a suspension. They do this by rendering the surface of the particle more water-repellent and destroying the hydrated sheath so that there is nothing to prevent the particles coalescing. In general, the cationic surface-active agents are useful for promoting sedimentation or flocculation, but it is worth noting that in most instances the same agent which in high concentrations promotes suspension in aqueous media will, in low concentrations, induce sedimentation.

The phenomena of suspension and sedimentation are made use of in ore flotation, and in grinding operations where a suspension of the abrasive substance gives more uniform results than would a block of the abrasive.

Adsorption

A number of miscellaneous applications of surface-active agents which utilise their ability to form surface films may be dealt with under this heading.

The corrosion of steam and condensate pipelines and equipment brought about by oxygen and carbon dioxide in the steam entails more frequent replacement of valves and lines. If the steam-carrying vehicle can be coated with a substance which prevents it being wetted, a high degree of protection from corrosion will be observed. This has been done in practice by the use of co-called "filming amines", long chain amines either dispersed, emulsified or rendered dispersible by chemical interaction which are applied at the feed water pump or at a point where it can be assured that the amine will be well mixed with the steam. The amines produce a film of molecular proportions on the metal surface, forming a barrier between the condensate and the metal which prevents corrosion.

The protection of metal surfaces against rust and corrosion often involves the use of surface-active agents. The surface-active agent itself may act as inhibitor as in the case when alkylolamides are added to cutting oils, or it may merely assist in the application of an inhibitor of another type by causing adequate spreading or promoting adhesion. This latter property of promoting adhesion is a characteristic of cationic surface-active agents and advantage is taken of it in many industries. A surface to be coated will usually be associated with a negative charge, so if the coating substance can be made to assume a positive charge the chances of adhesion are greatly increased. Cationic surface-active agents are added to paints which have to be applied to damp surfaces and in all such cases the cationic material, in the presence of moisture, increases the positive charge on the coating material, the water interface is displaced and adhesion results where it would not otherwise have been possible.

Handling Surface-active Agents

The handling of surface-active agents does not usually present serious difficulties, but it would be wise, on all occasions, to contact the manufacturers of the agent in question for his advice on suitable materials for construction. Some surface-active agents, because of their powerful wetting properties, tend to accelerate rusting, whereas others may well be powerful rust inhibitors, and are indeed used for this purpose, as previously mentioned. Plastics materials are very suitable for holding and conveying solutions, but occasionally, if thick tubing which is subject to considerable flexing is employed, cracking may be accelerated. Manufacturers of plastics can give sound advice in this direction.

A point of particular importance is that lines to metering and spraying apparatus should be kept completely filled as the foaming nature of surface-active agent solutions tends to entrap air and renders this type of apparatus unusually difficult to operate efficiently and accurately under these conditions.

REFERENCE
1. "A Dual-purpose Agent for Tank Cleaning and Breaking Emulsions", L. R. B. Shackleton, W. E. L. Taylor and C. D. Moore, *The Motor Ship*, **39**, No. 466, pp. 580-2.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

Suspension Systems Use Coil Spring, Rubber and Compressed Air

THE Elipress spring system, developed by Società Saga, Milan, is a development of this company's Eligo spring, which consists of a helical compression spring encased in rubber in such a way that the steel and rubber act in parallel in a complementary way. Whereas the Eligo spring is mainly used in rail coaches, the Elipress spring is a development for use in the suspensions of road vehicles as well.

The Elipress consists of a helically-shaped cylinder which incorporates a coil spring. The ends of the spring are sealed so that air under pressure, and thus a third elastic system, is introduced.

For the Eligo spring, which works without air, the following advantages are claimed:

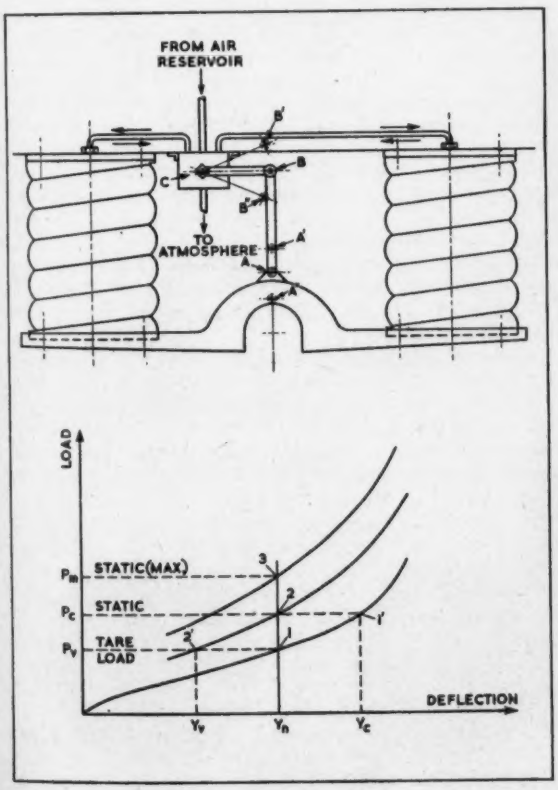
1. Damping of the single windings under dynamic loads.
2. Peak strains in the coil spring are reduced, since rubber in such conditions undergoes stiffening.
3. The steel spring is protected from surface corrosion.

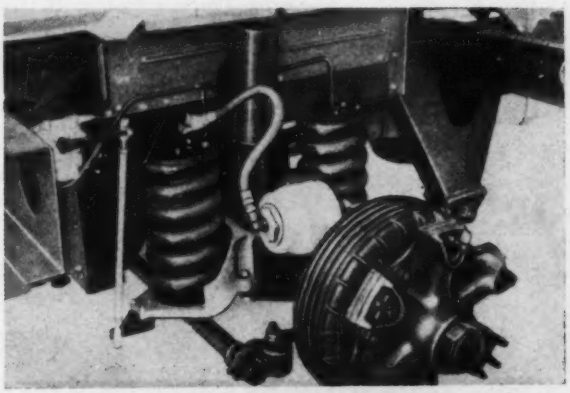
The difference in characteristics between the two systems is as follows. Whereas in the Eligo system flexibility decreases with increasing loads, it is claimed that with the Elipress, with the assistance of compressed air, it is possible to maintain flexibility even with the heaviest loads.

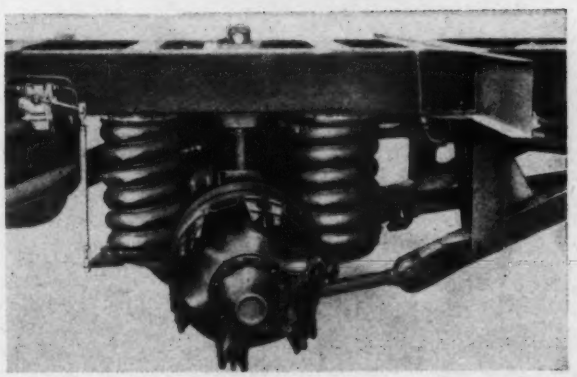
The diagrammatic sketch and diagram illustrate the working principles. The Elipress spring air system is maintained in communication with the atmosphere until a given deflection (Yn) corresponds generally to the tare load (Pv). When the static yield Yn is reached, up to which time the Elipress behaves exactly in the same way as the Eligo spring, the air distributor valve comes into operation. With a normal Eligo spring proceeding from a static load Pv to Pc, the point 1′ would be reached, corresponding to a deflection, Yc. But with the Elipress each increase of deflection beyond Yn causes the displacement of the pivot points of a linkage which controls the air distributor valve. The cylindrical air spaces in the Elipress springs are thus closed to atmosphere and ports are opened into the distributor. The load-deflection curve of the system now alters to provide a new configuration of balance corresponding to the deflection Yn. Under the load Pc it will not pass to the point 1′ of the diagram, but to the point 2.

Conversely, by a decrease of the load, the configuration of the linkage becomes of the type A′ B′ and the distributor acts, stopping the air inlet to the distributor and opening the outlet ports of the springs to atmosphere until, instead of descending from point 2 to point 2″, this latter point is not reached until the point 1 and the deflection Yn.

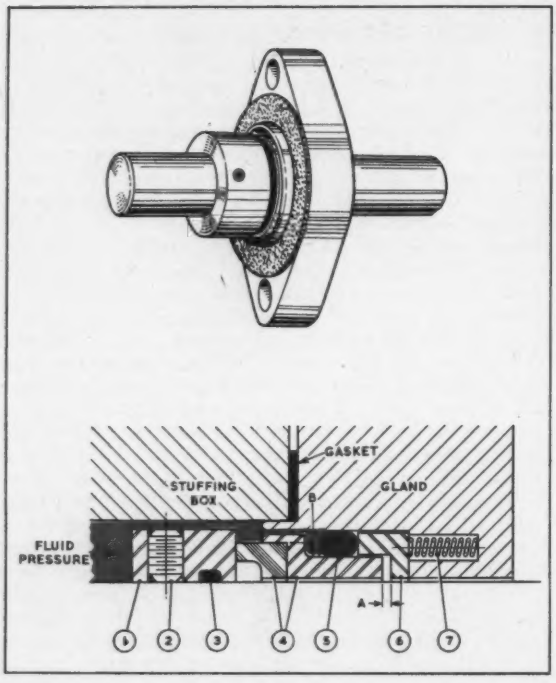
The above explanation is a consideration of the system under static conditions. The distributor is checked and adjusted so as not to react to dynamic strains, at least within determined limits of time. As a result, jolts of the vehicle (which generally last only for fractions of a second) do not operate the distributor. But in the event of the vehicle running on long curves, in which case the springs on the outer side would tend to deflect, the distributor can be adjusted so as to compensate by loading the outer springs with advantageous results.







New Seal Relies on Balanced Hydraulic Pressure Alone

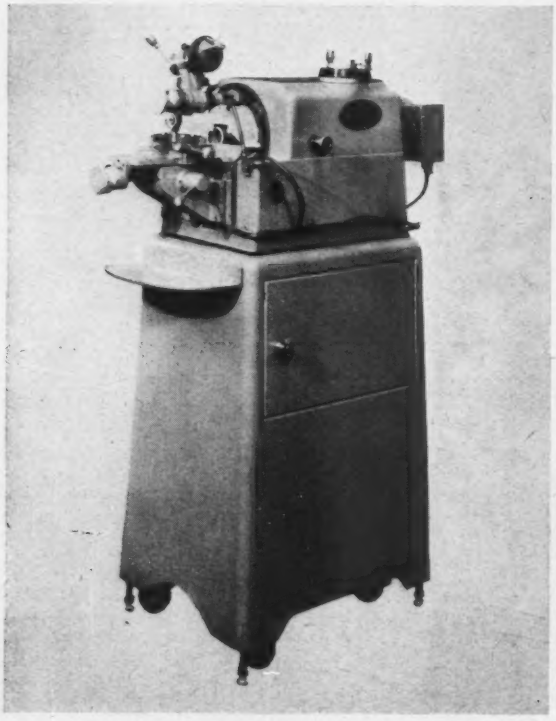


MECHANICAL seals that employ the balanced-pressure principle are not new, but, in general, considerable reliance is placed on additional pressure provided by coil springs to ensure closure of the seal faces during operation.

In a new mechanical shaft seal, known as the Counterpoise seal, manufactured by A. W. Chesterton Co. in the U.S.A., reliance is not placed on springs for sealing during operation. The springs are merely used to hold the faces in sealing contact when fluid pressure is below the design minimum.

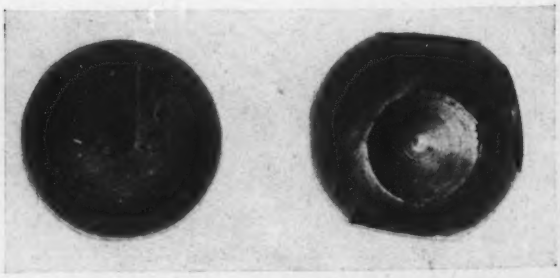
The sectional drawing shows the operating principle of the seal. When little or no fluid pressure exists in the pump stuffing-box, the springs (7) acting against the floating adaptor (6) close gap A and load the stationary seal ring (4), thus ensuring the face closure. When the fluid pressure increases above a designed minimum, its action over the inboard area of the dynamic O-ring (5) will counteract spring force and open gap A. At this point the fluid pressure alone, acting over the area B, will provide a balanced and perfectly uniform face closure. With this arrangement it is claimed that, as the seal is balanced with its own components at all pressures, there is no need for a special sleeve or shaft-shoulder. Additional advantages claimed by the manufacturers are that the sealing faces are evenly worn, as they are always kept parallel; a wide range of varying pressures can be dealt with; the small springs that are used cannot become clogged or corroded; there is no turbulence caused from a complicated rotating mass; and a large inventory of seals is not required as with custom-built seals.

Drill Grinder for Producing Self-centring Drill Points



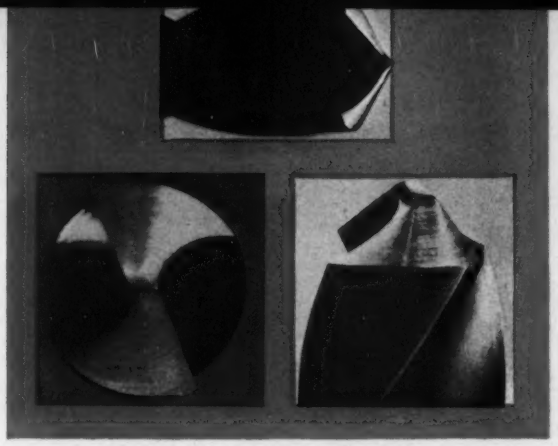
THE Cincinnati Spiropoint drill-sharpening machine has been developed to grind drills to a new form of point geometry. The spiral point that the machine produces is said by the manufacturers greatly to improve accuracy in hole positioning, to produce holes closer to size, to eliminate centre punching, to reduce burrs, increase drill life and reduce the drill thrust force required. It is also claimed to reduce the need for secondary operations such as reaming and to produce less workpiece distortion, owing to less heat generated by the reduced thrust during the drilling operation.

From accompanying photographs it will be seen that an actual point is produced at the centre of the drill. On contacting the work, the drill automatically centres itself, and it is claimed that this self-centring action continues throughout the drilling operation. This self-centring action is well illustrated by the right-hand ball bearing below, which was



drilled with a Spiropoint drill. The left-hand ball bearing is shown scarcely marked by a drill ground in the conventional manner. This action is said greatly to reduce the need for expensive bushings. For sheet metal drilling the self-centring action of the spiral-point drill is stated to be particularly helpful in obtaining truly round holes in thin soft metal and when the drill is held by hand. For sheet metal application the spiral-point drill is given a point angle of 180 deg. as opposed to the usual 118 deg.

The complicated shape of the spiral point is said to be obtainable on the Spiropoint drill sharpener in a few seconds. The machine is supplied complete and ready to run with its own motor-driven dust collector housed in the cabinet base. U.K. agents for the machine are Charles Churchill & Co. Ltd.



Special-purpose Mobile Crane

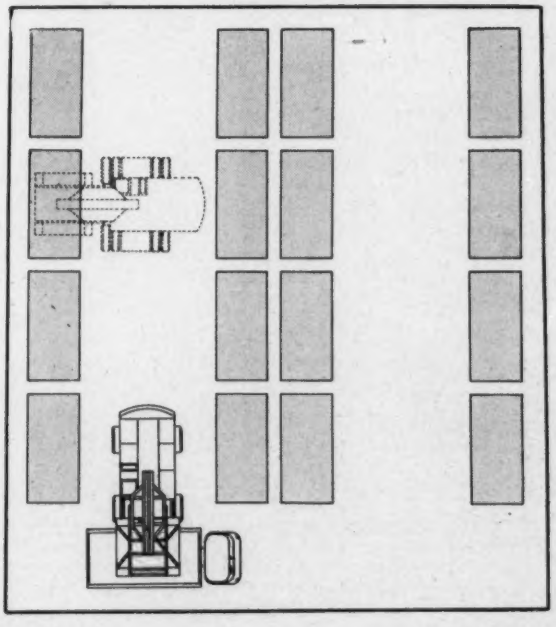
A SPECIALLY designed Cole's Emperor mobile crane has been produced for the handling of large lorry- and ship-borne containers in the congested conditions that sometimes prevail at quaysides. It was necessary to provide a crane that could work in a narrow aisle of containers, hold the load firmly so that it did not swing, travel and manœuvre at a reasonable speed when fully loaded, keep the container as nearly vertical as possible and, at the same time, lift the load clear of other containers and transport vehicles. The conditions are shown in the accompanying diagram and photograph.

Instead of a normal strut-type jib, a special mast made from rolled steel sections and plates in the form of a "T" or hammer-head was produced. This was hinged at its lower end in support brackets at the front of the superstructure. A fabricated steel container carriage projects horizontally from the mast and is raised by means of the hoist rope which passes over pulleys on the cross piece of the T-shaped mast and is attached centrally to the carriage or frame. Four steel rollers on the carriage run in the main vertical channel of the mast which acts as a restraining guide-way and permits a smooth hoisting and lowering action. Tilting the mast a few degrees so that the load rests against a pad has eliminated swinging and prevents damage to the container. Hydraulically-operated telescopic backstops prevent the mast being tilted more than 7½ deg. beyond the vertical position.

The crane is powered by diesel-electric transmission. This comprises a diesel power unit directly coupled to a variable-voltage generator which supplies current to the separate motors of the hoist, derrick, slew and travel units. Maximum lifting capacity, which is based on two-thirds of the tipping load, is 12½ long tons at a radius of 11 ft. 3 in. at which the lifting mast is in the vertical position required for normal operation.

A feature which allows the crane to work in a narrow aisle is its short tail radius and ability of the tail to pass over the empty trailer when slewing. Thus valuable saving in aisle space is claimed and it also means that the crane can slew before the trailer is driven away.

The chassis is specially designed for crane duties and fabricated from steel sections and plates. The chassis is powered by a 34-h.p. electric motor via a gearbox and rear axle differential. The front axle is a steel beam with stub axles swivelling on case-hardened nickel steel king-pins carried in bronze bushes. The superstructure revolves on a large-diameter Roballo double ring of steel balls running in hardened races.



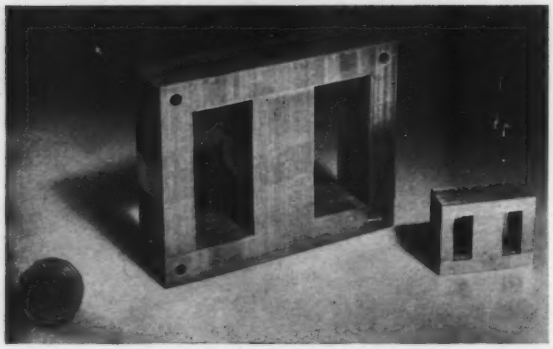


Fig. 1. Comparison of sizes of audio-frequency transformer cores in Mumetal nickel-iron stampings (shown right) and silicon-iron stampings (left). Photo: Telegraph Const. & Maintenance Co.

by C. GORDON SMITH, M.A., A.M.I.E.E.*

SPECIAL-PURPOSE ALLOYS FOR INSTRUMENTATION AND ELECTRONICS

Special properties are offered by nickel as an alloying agent and as a material in its own right for use in instrumentation and electronics applications

ALTHOUGH nickel has a number of useful properties, its most outstanding characteristics are found when it is alloyed with other metals. The more widespread applications include those depending on the features of corrosion resistance, performance in service at high temperatures and the faculty for enhancing mechanical properties, particularly in steels and cast irons.

The materials described in this article, however, have special properties of a rather less familiar and obvious nature. They are used, on a relatively small scale, to perform special functions, although often in some vital capacity. Bearing in mind that such uses are, in many cases, for components weighing a few ounces or even less, the wide extent of such applications can be judged by the fact that they account for something over 5 per cent of the total usage of nickel.

A large proportion of these materials are based on nickel-iron alloys or their derivatives. The special properties are related to ferro-magnetic phenomena, either directly or as an indirect effect of volume changes associated with magnetic transformations.

From the nickel-rich end of the diagram in Fig. 4 it will be seen that the Curie point or magnetic transformation curve rises to a maximum and then falls away to room temperature at about 30 per cent nickel. Below this nickel content, the system is complex and the alloy may exist in one or other of two states, dependent on its previous history. While these alloys are not the subject of practical application, it is of interest to note that the curious anomalies observed in this region gave the impetus to more detailed study, including comprehensive investigations of the whole system, during the course of which quite startling properties were discovered, which have now been put to a number of uses. The materials can be classed as:

1. High-permeability alloys.
2. Alloys with low Curie points; e.g., those which exhibit rapid changes of magnetic properties at ambient temperatures.
3. Alloys with low thermal expansion.
4. Alloys with constant elastic properties.

* *Development and research department, Mond Nickel Co. Ltd.*

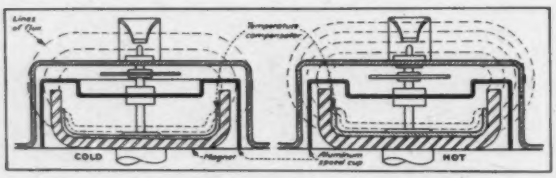


Fig. 2. Temperature compensator in General Motors' drag-type speedometer.

High-permeability Alloys

In the simple nickel-iron system shown in Fig. 5 a peak is found in the permeability curve at about 80 per cent nickel, giving a value of something of the order of 10,000, which may be compared with values of the order of a few hundred shown by high-grade magnetic iron. By the addition of further minor constituents, and also improvements in techniques of production leading to higher purities, permeability values now of the order of 20,000 to 30,000 are available in quantity on a commercial scale. Some special grades are now available in limited quantities with initial permeabilities of up to nearly 100,000. It should be remembered, however, that these high-permeability alloys saturate at comparatively low field strengths and thus are not so effective for use in high field strengths as other materials.

One of the chief uses of these materials is for the screening of instruments likely to be affected by stray magnetic fields, for example, in electrical indicating instruments and more particularly in cathode-ray oscillographs. The efficiency of magnetic screening is directly proportional to the permeability of the material used; thus in many cases effective magnetic screening would be quite impracticable were it not for the availability of these high-permeability alloys.

Another widespread use is in transformers used both for indicating instruments and in communication circuits carrying audio and high-frequency currents. In the former, errors in measurements are largely caused by transformer flux leakage, which is directly related to the permeability of the core. The inherent low magnetic losses in these materials also effectively reduce phase errors.

In communication transformers, high permeability not only reduces size, but enables performance to be improved particularly in respect of frequency response. With the latest materials available, it is now possible to cover in a single transformer the whole television video range (for example, from a few c/s to several Mc/s).

For use at higher flux densities nickel-iron alloys with lower percentages of nickel are made. These give permeabilities still higher than iron or ferro-silicon alloys, and owing to the increased resistivity have reduced eddy current losses. Transformers and inductances for handling small power quantities at audio-frequencies frequently depend on the use of such nickel-iron alloys.

Square Hysteresis Loop Alloys

Square hysteresis loops can be achieved by reaching a high degree of orientation in the production of the alloy strip, and Fig. 8 shows the effect that can be achieved in a 50 per cent nickel-iron alloy.

The square hysteresis loop has a number of important effects when used for the cores of inductors, and some examples of how these can be exploited are given below.

RECTIFIERS—The effect of the application of a sinusoidal voltage to an inductor containing a core of magnetic material with a normal type of hysteresis loop is well known and produces a characteristic kinked wave form in the current. If, however, this core is replaced by a material with a substantially rectangular hysteresis loop, there is a marked further change in the wave form of the output current as shown in Fig. 6. It will be noted that in this case the current is stationary for an appreciable portion of the cycle. This effect can be usefully applied in devices used for the rectification of alternating current by mechanical switching. The operating contacts can be timed to open during the period of no current flow, and thus the difficulties of sparking are avoided. This type of converter has been successfully applied to large installations and particularly for the production of direct current for electrolytic processes.

MAGNETIC MEMORY DEVICES—If a pulse of magnetising current is applied to an inductor of sufficient magnitude to approach saturation, the core is left in a condition shown at R_1 in Fig. 10 after the current ceases. Any further application of current in the same direction will have no appreciable effect on the magnetisation of the core and, as a result, no output voltage will be developed across the secondary winding. The core is thus insensitive to any further impulses in this direction on account of the effect of the initial pulse. A second stable state may be obtained by the application of a pulse in the opposite direction. These principles can be readily adapted to the storage of information, and form the basis of memory systems used extensively in electronic computers.

MAGNETIC AMPLIFIERS—The third and probably most important application of square-loop alloys is in magnetic amplifiers.

The principle of the magnetic amplifier has been known for a long while. It depends on the effects accompanying the saturation of a magnetic core; as saturation is approached, permeability changes very rapidly, and thus the inductance of a coil wound on such a core can be made to alter as the d.c. magnetising current is varied. The current in one winding can thus, in effect, be controlled by the voltage applied to another, and with appropriate arrangements a big amplification effect can be obtained. Much increased efficiency of magnetic amplifiers has been achieved by the use of modern magnetic materials in conjunction with the use of the dry plate rectifier, and is now resulting in widespread application.

One of the important features of magnetic amplifiers is their ability to operate at very low frequencies or with direct current. They are thus very useful in automation and control systems based on small direct-current signals, for example, thermocouple output, etc. In such applications they are small, compact and rigid in comparison with thermionic amplifiers. They are used extensively in aircraft applications, for example, for jet-pipe temperature control.

Magnetic Compensation Alloys

As was shown previously, a reduction of the nickel content to about 32 per cent results in alloys with a magnetic transformation point only slightly above room temperature. Such materials exhibit a rapid change of permeability with temperature, a property which can be used with advantage in some types of compensating systems. Particular examples are in the case of speedometers of the drag disc type and the normal kilowatt-hour electricity meter.

In both these instruments quantitative use is made of the controlling torque set up by eddy currents in a disc rotating in a magnetic field. This torque is affected by changes in temperature because of the high temperature coefficient of resistance of the disc material. This effect can be compensated by using a shunt of temperature-sensitive magnetic alloy. This diverts an increasing proportion of the useful flux from the permanent magnet system as temperature rises, permitting accurate compensation for the temperature effects of resistance, and also for other less important causes, such as temperature variation in the properties of the magnets, etc.

It should be noted that in these cases the methods of temperature compensation usual in other electrical instruments cannot be used, because there is no physical access to the circuit in question.

These temperature-sensitive magnetic alloys may also be used in various other ways; for example, in thermal cut-outs and control devices.

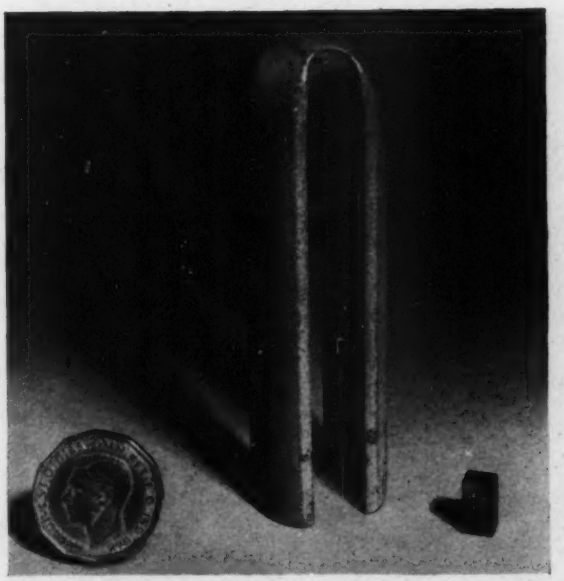


Fig. 3. Old and new magnets for telephone receivers. The large one is a tungsten-steel magnet used in the "candlestick"-type instrument; the smaller an Alcomax magnet used in a modern earpiece. (Photo: Permanent Magnet Assoc.)

Permanent Magnets

Alloys developed from nickel, iron, aluminium and cobalt, with various minor additions, show enormously improved properties compared with the earlier materials such as tungsten and cobalt steels. It is of interest to note that the metallurgical constitution of these alloys is entirely different from the martensitic structure in the earlier types of magnet steels. Nevertheless, the new materials are extremely hard and thus have to be made usually by casting or sintering. Their use can result in big savings of space and weight in the majority of typical applications for permanent magnets. In addition to their greater power and, perhaps contrary to expectation, the alloys are far more stable to the effects of mechanical shock and heat.

In the electrical field they are widely used for indicating instruments of all types, for loudspeakers, polarised relays, magnetic pick-up and play-back heads, etc. Their high energy content has resulted in their use for many applications in which electro-magnets were previously used; and they are also finding wide application in a number of mechanical uses developed on account of their high attractive power.

Magnetostrictive Materials

Most ferro-magnetic materials undergo changes in dimensions when magnetised. The fractional change in length, or linear magnetostriction effect, varies considerably in magnitude, and while it is related to other magnetic properties, its dependence on the latter is not at all obvious. The effect on nickel itself, and certain nickel alloys with iron and/or cobalt, is particularly large, and can be turned to practical account. The principal application is in the construction of transducers for the production of ultrasonic energy. These are used extensively in echo depth sounding at sea, not only for navigational purposes but also for fish and whale detection. The use of ultrasonics for cleaning, soldering and machining is also showing some promise.

In communications, uses are developing for filter and oscillator elements of high precision based on mechanical oscillating systems driven by magnetostrictive methods.

Other Magnetic Materials (Ferrites)

In dealing with magnetic materials used in instrumentation, communication and electronics, it will be found that nickel alloys will fulfil almost all the major technical requirements. Nevertheless, the picture would not be complete without some reference to the recent development of ferrites. These materials are not metallic alloys, but ceramic materials, developed from the ancient lodestone and are related to magnetic oxide of iron (Fe_3O_4). An extremely interesting series of materials has been developed by replacement of part of the iron with other metallic radicals. These included manganese, zinc, nickel, cobalt and barium. Such ferrites find their counterparts in most classes of magnetic material, exhibiting high permeability or the properties of permanent magnets or magnetostrictive alloys. Their big advantage is that they are practically non-conductors and thus in alternating fields do not develop eddy current losses.

However, this last advantage may be offset by other less desirable characteristics, and while ferrites are undoubtedly of extreme interest as a recent technical development and possess some very outstanding properties, they have technical and economic limitations. These new materials should be regarded in their own right and used for new applications exploiting their own particular merits. It is a mistake to draw indiscriminate comparison with metallic magnetic materials, which will still continue to hold their own in very many applications.

Low Expansion Alloys

In heating a nickel-iron alloy, a change of volume is

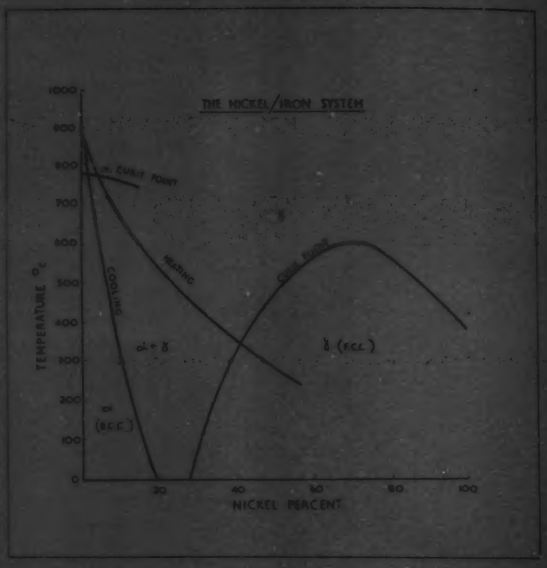


Fig. 4. Constitutional diagram of nickel-iron system.

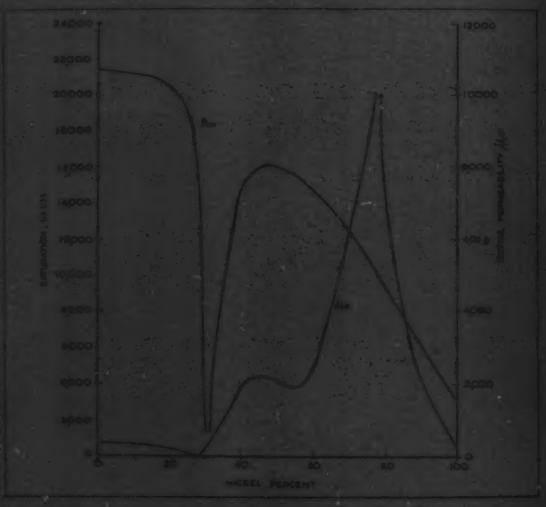


Fig. 5. Graph indicating relationship of permeability to nickel content.

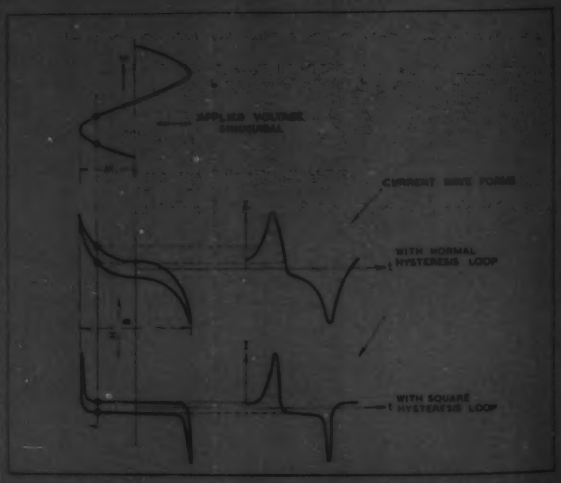


Fig. 6. Effect of hysteresis on wave form.

experienced in passing through the Curie point. The latter is not well defined and the transformation takes place gradually over a fairly wide temperature range. The decrease in volume accordingly modifies the effective thermal expansion. The effect is most marked in the 36 per cent nickel-iron alloy, which shows a remarkably slow expansion over a temperature range up to about 80 deg. C.; this alloy is well known as Invar, Nilo 36, and by a number of other trade names.

While such materials with very low temperature coefficients of expansion have certain uses, for example, in clock pendulums, geodetic tapes and mountings for gunnery equipment, the wider applications are for temperature indication and control purposes as well as for glass-to-metal seals. In such cases, operation over a wider range of temperature is generally required and other alloys may be selected to better advantage, which, although having larger expansion coefficients at room temperature, may have a considerably lower total expansion over an extended temperature range.

For temperature regulation purposes the rod-type thermostat is the type of device most frequently used where precise control by operation of an electric contact is required. In other cases and for purposes of temperature indication, the use of bi-metal strip is more general. This allows a greater flexibility in design as regards deflection and operating force, which can be obtained for a given temperature difference. The low expansion side of the bi-metal strip is invariably a nickel-iron alloy of some type or other. The old-established combination of 36 per cent nickel-iron with brass is still widely used, although there are a large number of different combinations of alloys available. These are made to meet special requirements, as, for example, for use in corrosive media, over large temperature ranges, or with sensitivity varying with temperature. Alloys with high magnetic permeability and high or low electrical resistivity are also available, but usually these special combinations require some small sacrifice in sensitivity as none of the complex alloys has as low an expansion as the basic nickel-iron alloys.

Constant Modulus Alloys

The expansion anomaly in the nickel-iron series is associated with a number of other effects resulting in critical changes in properties near the Curie point. The temperature coefficient of elastic modulus is a case in point. Nearly all materials have fairly large negative temperature coefficients of modulus; for example, they become weaker as the temperature increases.

In the anomalous region of the nickel-iron series, however, there is a fairly large positive peak, on either side of which can be found compositions with zero temperature coefficients of modulus. The addition of a third element such as chromium has the advantage of flattening this peak and making the composition for zero temperature coefficient less critical. This forms the basis of the material Elinvar, originally developed for use in watch springs. The addition of chromium also improves the mechanical properties, which are not very good for the straightforward nickel-iron alloys.

In addition to their use for watch hair-springs, these so-called constant modulus alloys find a number of important uses, for example, for springs of precision weighing machines, in the diaphragms for aneroid capsules or in the tubing for Bourdon gauges. Mainly with the object of increasing the elastic properties of these materials, a large number of modifications in composition have been introduced, the most successful of which are the range of precipitation hardening alloys such as Ni-Span C, i.e., nickel-iron-chromium-titanium, and Nivarox, nickel-iron-chromium-beryllium. Some of these materials also possess the additional advantage of magnetostrictive properties and

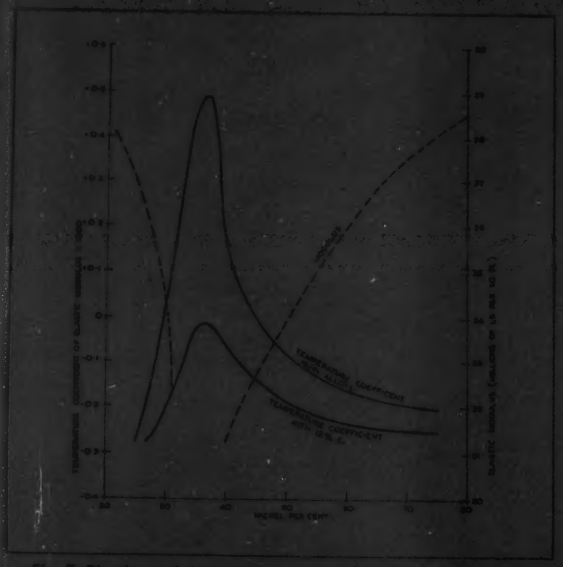


Fig. 7. Elastic modulus and temperature coefficient of nickel-iron alloys.

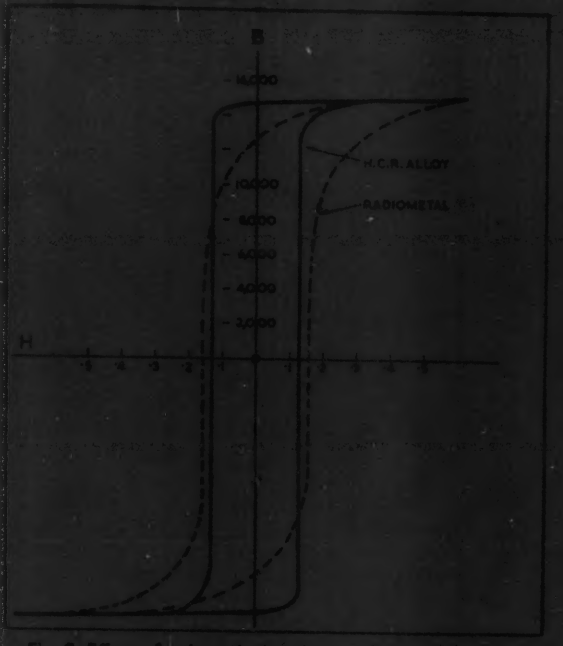


Fig. 8. Effect of orientation on hysteresis loop for 50 per cent nickel alloys.

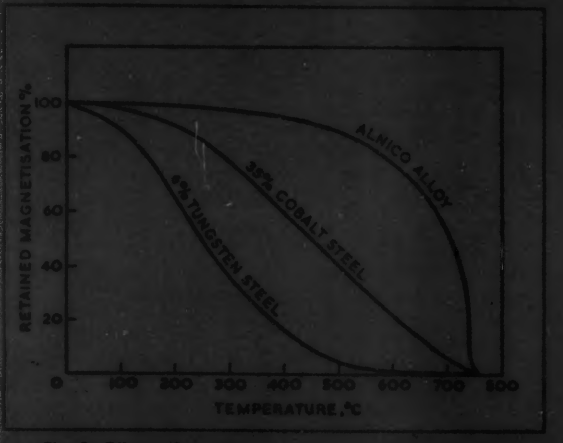


Fig. 9. Effect of temperature on magnetic properties.

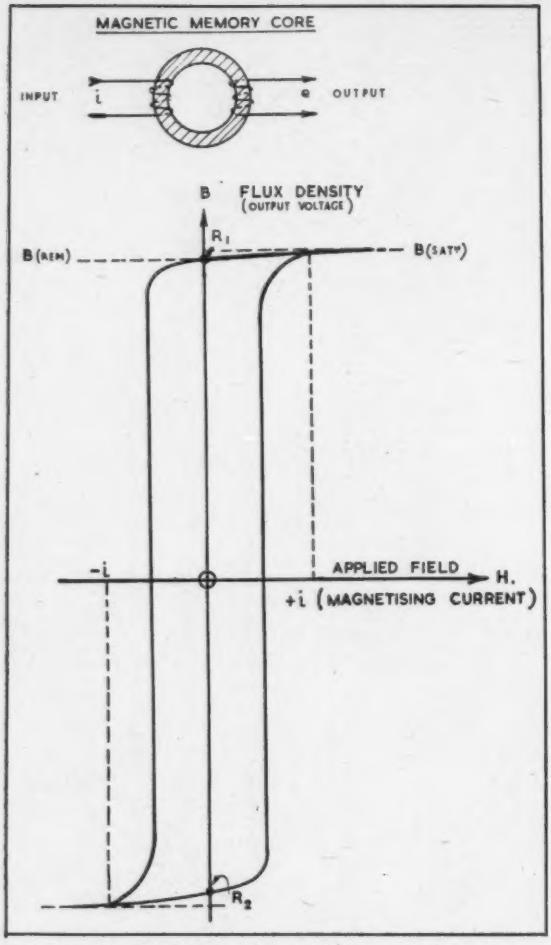


Fig. 10. Hysteresis loop as applied to magnetic memory core.

thus may be used with effect in the construction of mechanical frequency standards and delay lines working over a wide frequency range.

Miscellaneous Applications

SPRING MATERIALS—These cover a fairly wide range of alloys, the main interests being their durability and improved resistance to corrosion. They include materials hardened by means of cold working and also those with precipitation hardening. For use at elevated temperatures very good performance can be obtained from nickel chromium alloys of the Inconel or Nimonic type.

THERMIONIC VALVES—A large proportion of the internal components of thermionic valves and cathode-ray tubes are made from either pure nickel or nickel alloys. These metals possess a convenient combination of many properties particularly suited to this type of work. For example, they can be produced free from impurities of volatile metals and can be readily degassed. They do not pick up undue amounts of oxygen or other contamination during works processing, and they can be fabricated easily by all normal methods; welding and joining present no difficulties. In addition to anodes, support wires, etc., nickel alloys find important applications in the cathodes of many thermionic emitters where the above-mentioned properties are required in conjunction with special properties affecting ionic emission.

SPARKING PLUGS—Nickel-silicon and nickel-manganese alloys offer good resistance to spark erosion and attack from

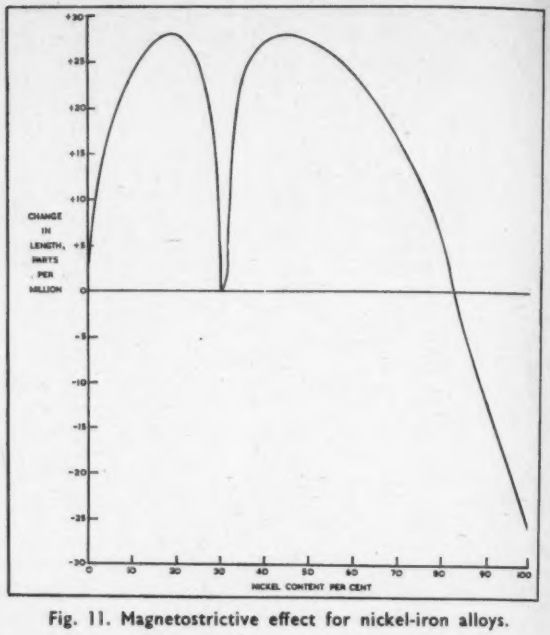


Fig. 11. Magnetostrictive effect for nickel-iron alloys.

lead and sulphur. As well as being good electrical conductors, they are easier to weld and have better heat conductivity than the nickel-chrome alloys.

POWER SOURCES—The operation of communication or electronic equipment may often depend wholly or partially on special power supplies. These may be either alternating or direct current at high or low voltages. Nickel-base materials find extensive use in the following power supply applications:

Transformers, Rotating Machines—In the case of alternators for small self-contained systems as used in aircraft or missiles, there are advantages to be found in the use of high frequencies, for example, 400 c/s or 1-2,000 c/s. Particularly in the case of the latter, Ni-Fe transformer cores may offer advantages, the reduced losses more than compensating for their lower saturation.

Transistor Converters—A recent development of considerable promise is a d.c. to a.c. converter based on the use of transistors and transductors, the latter requiring magnetic cores with square hysteresis loop characteristics, for which nickel-iron alloys are particularly suitable. A very high efficiency of conversion is claimed. The device may be followed by a transformer and rectifier unit, making, in effect, an efficient and compact d.c. transformer.

Accumulators—The use of accumulators for d.c. power supplies is common practice. The reliability and durability of nickel-cadmium batteries has been established for many years, but the conventional types suffer from the disadvantage of rather high internal resistance, and thus their use, which often needs to be in conjunction with engine-starting duties, has been limited. The recent introduction of sintered plate construction has, however, more than overcome this disadvantage and as a result increasing use is being made, despite a higher initial cost, of this type of battery, which shows, in addition to technical advantages, an economic saving by increased life and much reduced maintenance costs. In addition, it has now been found possible to produce in the smaller sizes, completely sealed batteries with even lower maintenance requirements, and with no hazards from contamination. In addition, improved performance at very low temperature is also offered.

This is an abridged version of a paper originally given at the College of Aeronautics, Cranfield.

designer's notebook

Capstan Torque Amplifier uses Carbon Drums and Wires

DRY friction torque amplifiers, of the type whose principle is illustrated in Fig. 1, have been used for some time in mechanical computers. They have been found to suffer from severe instability and from seizure brought about by a very small quantity of water or oil.

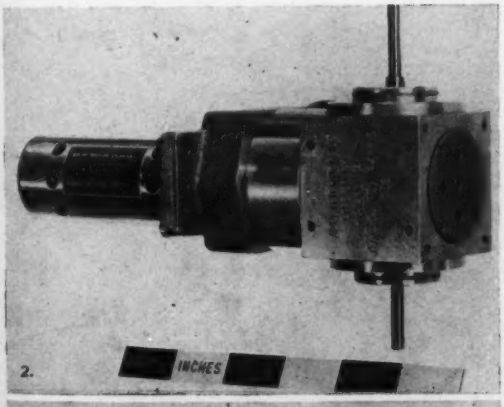
In a compact 1/40-h.p. torque amplifier (Fig. 2) developed by an Admiralty Establishment for use in such a computer, these troubles are said to have been overcome by the use of porous hard carbon drums continuously lubricated by centrifugal action. Wires are used instead of tapes, this combination being found to give a coefficient of friction of 0·14 and to lead to negligible wear. The amplifier is designed for a gain of 8 and the stability has been found to be much improved by the viscous damping introduced by the lubricant. To avoid distortion of the wires, they are enclosed in a grooved cage. The drum and wire assembly is seen in Fig. 3, together with the bevel gears which carry power from the motor to the drums.

It is said that amplifiers of this type have consistently shown negligible wear over test periods of 3,000 hr. with full load and with the input speed being varied harmonically with amplitude 300 r.p.m. and period 15 sec. When lubricated with suitable oil they will start and run at −40 deg. C.

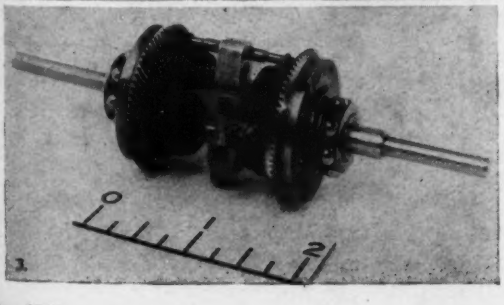
It is a characteristic of these mechanisms that they have a limited angle of wrap-up: about 2 deg. for a new amplifier and 3 deg. for a worn one. The stiffness in this zone is approximately 5 oz. in./deg.

Details for the E3 Mk. 1 illustrated in Fig. 2 are as follows:

Max. continuous output torque ...	10 oz. in.
Max. output speed	900 r.p.m.



2.


3.

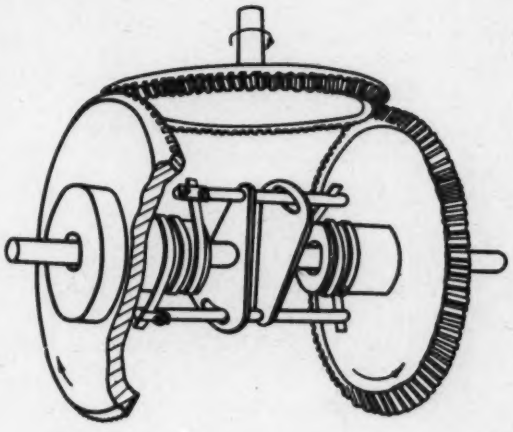


Fig. 1

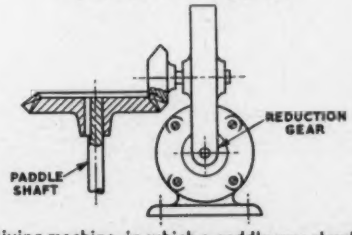
Drum speed	1,250 r.p.m.
Minimum gain	8
Weight, incl. 400-c/s motor ...	2 lb. 5 oz.

A larger (¼-h.p.) version of this amplifier is also made having a gain of 64 and a maximum rated torque output of 64 oz. in.

Crown copyright reserved. Photos reproduced with the permission of the Controller, H.M.S.O.

PROBLEMS IN DESIGN

Here is this month's problem



In a mixing machine, in which a paddle was slowly rotated by an electric motor, jamming of the paddle spindle sometimes occurred. It was found necessary at once to stop the motor and reverse the paddle spindle a few turns by hand to free the blockage.

Problem: Devise a mechanism whereby, when a certain adjustable torque value to turn the paddle shaft is reached, its direction of rotation is suddenly reversed. The motor shall run continuously in the same direction.

A sketch of the kind of drive originally used is shown above. The device shall not employ compressed air, hydraulic or electrical means to effect reversal. Speed of paddle shaft rotation is approx. 20 r.p.m.

Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12 × 12 in., please !), to The Editor, "Problems in Design No. 7 (May)". Closing date June 10.

(NOTE: The wording of Problem No. 6 set in our April issue contained an error which might prove misleading. The last line of this as printed should read ". . . reciprocation for each of its own revolutions". Entries based on the incorrect data and which have already been received, will, however, be judged on their merits.)

PROBLEMS IN DESIGN

Problem No. 4 (February): To provide a means whereby a rotating input shaft can be made to reciprocate angularly an output shaft on the same axis. Data: input rotates at constant speed, output to reciprocate angularly one complete revolution clockwise and then one complete revolution anti-clockwise. Neither shaft is to move axially. Two revolutions of input shaft causing one complete reciprocation of output shaft, preferably without cams and friction drives. Shaft size: 1 in. dia. Input speed: 100 r.p.m. Torque transmitted: 20 lb. ft. The mechanism to be contained within a radius of 6 in. about centreline.

This month the many entries received have been the result of careful thought and painstaking draftsmanship, providing us with a difficult task of selection which is now being undertaken in conjunction with highly-qualified referees.

There appears to be a tendency in some cases to submit entries which are examples of exquisite draftsmanship but of poor engineering: but it will be seen that some of the entries we have chosen are not in this category at all. They have been picked as hardware propositions only and, in our view, show a firm grasp of essentials.

The criteria upon which our selection was based are:

1. Fulfilment of the functional requirements of the problem as set.
2. Number of parts involved, i.e., simplicity.
3. Ease of manufacture and, therefore, cheapness.
4. Grasp of correct proportions.
5. Compactness.
6. Avoidance of sliding pairs.

Once again it is necessary to divide the entries into several categories, and the order in which we give these is not necessarily our order of preference. In the first category are those which employ a sliding element. J. Bottrill (Fig. 3) uses a crank mounted on his 2:1 input reduction gear to reciprocate a rack which drives a pinion on the output shaft. This is a simple solution, the undesirable feature being the sliding rack and the accurate machining this would necessitate. A somewhat neater solution using a sliding element comes from G. Bartholomew (Fig. 1). The mechanism has been designed for extreme compactness, the necessary 2:1 input reduction being accomplished in two stages. To the last gear in this train is fixed an eccentric to which a slider is fitted. This slider actuates a rocking frame which pivots about the input shaft. To the rocking frame is attached an internally-cut quadrant which drives a gear on the output shaft. It will be seen that with this arrangement a varying angular velocity will be given to the output shaft, but, there being no ruling against this, the mechanism is acceptable. Our only criticism is that a sliding element is used and there would be a need for a rather close tolerance machining.

In the second category we include what we consider to be standard mechanical answers based on sound principles. To ensure compactness, S. M. Ellis (Fig. 2) uses two internally-cut gear quadrants. His anxiety to avoid friction is very apparent! We consider, however, that the machining cost of this mechanism would be rather high. R. L. Hutchinson (Fig. 5) uses a crank and connecting rod to reciprocate angularly the large gear which drives his output shaft. A number of valid solutions of this sort employed internally- or externally-cut quadrants. A good example of the former type is that from R. A. Hammersley (Fig. 7). His proportions look sound. J. Feuillade's solution (Fig. 4), using standard externally-cut gears, appears reasonable and inexpensive to make. Excellent solutions in this category were also received from P. D. Hirst, J. A. Barnes, D. C. Faithfull, G. T. Dormer, K. G. Pawson, J. Munford, L. V. Russell, A. N. Brown, A. T. Wilkins, R. T. Lancaster and A. R. Black.

In the final category we put two rather unusual entries. D. Cookson (Fig. 8) proposes a 2:1 bevel gear on the input side which reciprocates angularly a bevel quadrant. Unfortunately, his proportions are a long way out. It would appear that, were a true 2:1 ratio actually drawn, the crank would have to be on the opposite side.

The final solution we found most interesting of all. It comes from G. W. Maurice (Fig. 6) and employs bevel drive, to each end of the transverse shaft of which is fitted a crank. Each crank is connected to a recirculating ball nut. This nut reciprocates the output shaft, torque restraint being provided by a U-piece to which the cranks are welded.

In conclusion, we would say that although we did not state what kind of velocity diagram was expected, we did not expect our readers to depart very far from simple harmonic motion. Some entries, however, employed half gears providing alternate meshing, an arrangement likely to give rise to alternate and instantaneous reversals of a fearsome and noisy kind.

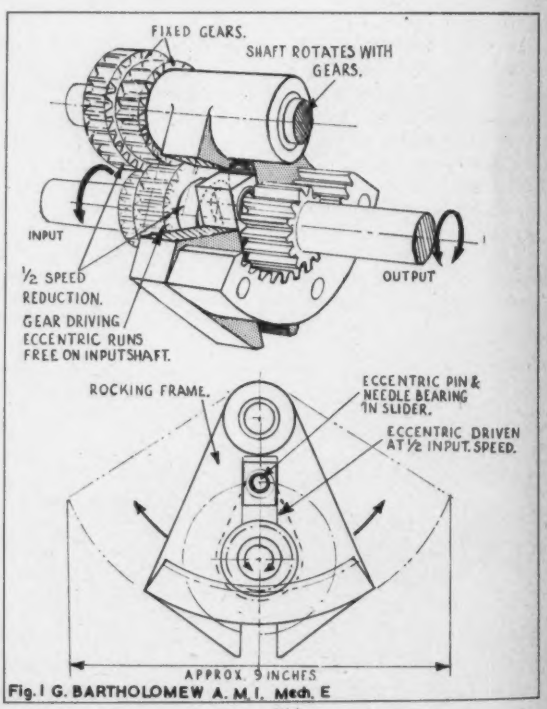
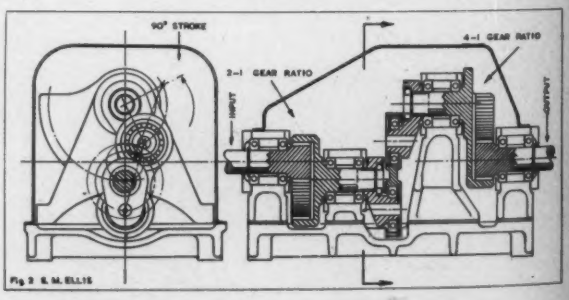


Fig. 1 G. BARTHOLOMEW A. M. I. Mech. E



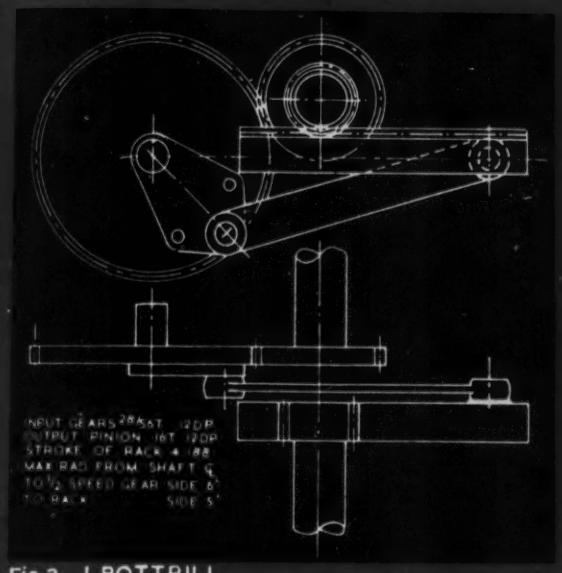


Fig. 3 J. BOTTRILL

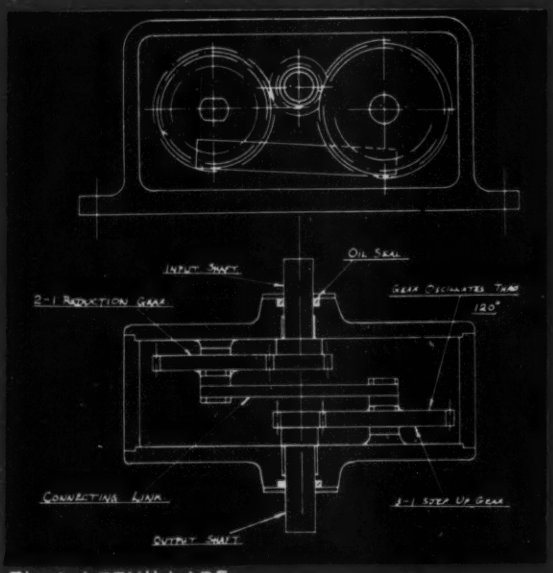


Fig. 4 J. FEUILLADE

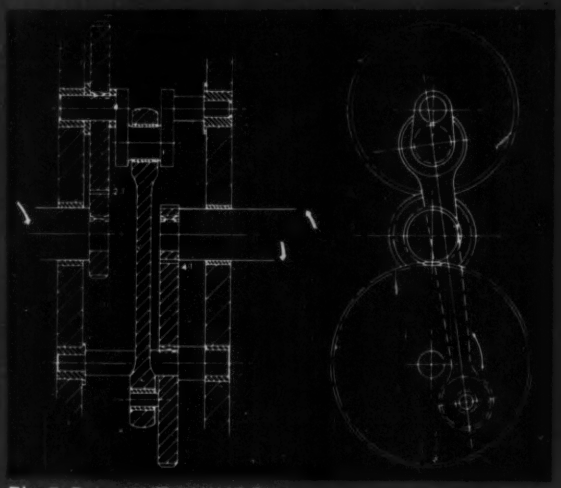


Fig. 5 R.L. HUTCHINSON

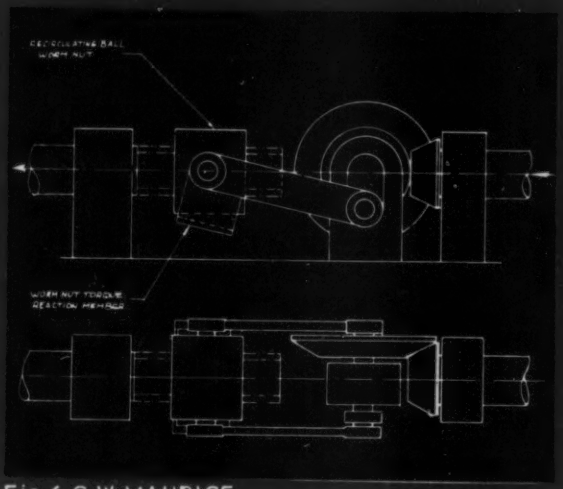


Fig. 6 G.W. MAURICE

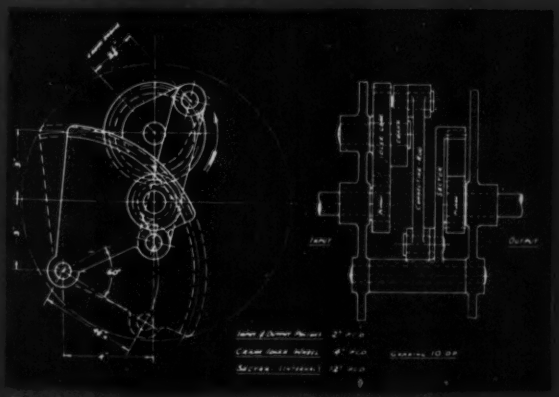


Fig. 7 R.A. HAMMERSLEY. G.I. Mech. E.

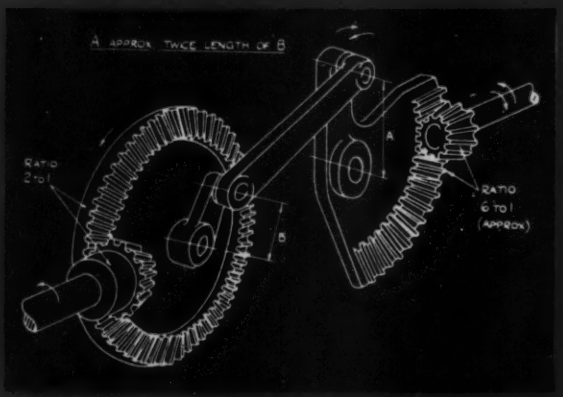


Fig. 8 D. COOKSON

SPRAYED CERAMIC COATINGS

A high degree of thermal- and abrasion-resistance can be attained by spraying components with ceramics, mainly aluminium oxide or zirconium oxide. The technique, with some examples of application, is described here

by J. ALAN SHEPPARD*

ALTHOUGH it is barely four years since the introduction of a practical and economical method of applying ceramic coatings by spraying, it has been adopted for many, widely differing applications in industry.

The currently sprayed ceramics are mainly alumina or aluminium oxide (Al_2O_3) and zirconia or zirconium oxide (ZrO_2). Zirconia has a melting point of 2,535 deg. C. and alumina 2,050 deg. C. Alumina has a hardness reading of 9 on the Mohs' scale — the same as sapphire — where diamond is only one degree above at 10. Both ceramics have high dielectric strength and are chemically inert.

Free-flowing ceramic powders of critical grain size and mesh are applied through the Metco ThermoSpray Gun. No compressed air is required, since oxygen and acetylene both propel and melt the particles, the powder being gravity fed from a canister through a siphon-jet nozzle which contributes to the high thermal efficiency of the unit. A small, electrically-operated vibrator is attached to the gun below the nozzle to ensure a smooth flow of these light-weight materials. For continuous production applications a hopper with greater capacity is substituted for the canister.

The control on standard guns is by a manually-operated trigger, but for production work the trigger is air-operated and can be electronically-actuated through a specially designed panel with modules for co-ordinating spray with movement, etc. A flowmeter indicates the correct consumption of gas and acetylene. There are no moving parts on the gun or the ancillary equipment.

A deposit efficiency of over 95 per cent subscribes towards the high-spraying speeds at very low cost. However, the physical properties of these ceramics can be altered within quite wide limits by varying spray technique; this, in turn, affects the spraying speed, but it approximates in the vicinity of 2½ lb./hr. This can be translated into an alumina coverage of about 150 sq. ft./hr. × 0·001 in. thickness, or *pro rata*. Zirconia is sprayed at a little less than half this speed.

One of the earliest applications combined the thermal- and abrasion-resistance of alumina. The exhaust venturis of guided missiles are given a protective coating of between 0·020 and 0·030 in. thickness ceramic which resists the attrition of the hot gases as well as providing a thermal-barrier (see Fig. 1). Wherever the high melting point refractory qualities are required, a slightly porous deposit is deliberately applied in order to increase its effectiveness and resistance to severe thermal cycling. If the base material is not oxidation-resistant, it is necessary first to spray an oxygen-barrier substrate, such as nickel chrome. This under-coating is applied with the same gun, or by conventional wire-metallising, to a thickness of 0·004-0·005 in. and has the further advantage of increasing the bond strength.

The preparation of the base metal to receive a thermal-barrier deposit is almost invariably by blasting with angular steel grit, or a similar angular abrasive, to clean the surface and concurrently provide a mechanical key. A grade 20-24 grit is most satisfactory. A high standard of preparation must be maintained as otherwise stresses, due to the radical differences in thermal expansion rates between most of the usable base materials and the ceramic layer, will tend to destroy the bond in sheer.

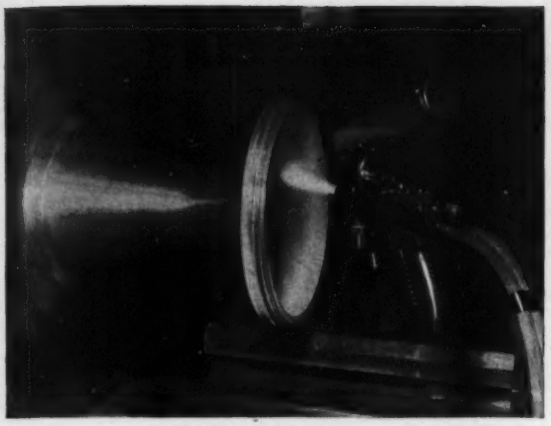
A 0·010-in. thickness of alumina has prevented or reduced the overheating of torches, cutting lances, flame brooms and flame nozzles. Burners, used in the removal of mill scale from slabs of hot-rolled steel, had a serious problem with heat inflow to the burners. Water cooling not only added to the cost, but also rendered them more awkward to operate. The ceramic coating is applied at a basic cost of well under 5s. per sq. ft. Due to the rapid elevation of temperature at 800 deg. C. generated in the starting cycle, the chamber of jet engine starters would immediately have a 0·030-in. thermal expansion, or creep, causing a radical decrease in operating efficiency. The sprayed ceramic thermal barrier now holds expansion at a maximum of 0·010 in. and thus eliminates the necessity of removing the chamber after three starts and the installation of shims to prevent turbine blades from rubbing.

Moulds for casting aluminium are fabricated from cast iron. A thin (about 0·006 in.) coating of alumina creates a heat barrier so that the molten aluminium will flow to completely fill the mould. Not only is the life of the mould increased by from five to ten times more than paint coatings, but the ceramic also gives a smoother texture to the cast aluminium than a coarse, sand-textured paint.

Graphite and dental crucibles, metal pouring troughs and heat-treating equipment are further thermal-barrier applications for sprayed ceramic coatings. Many more are completing trial and each new addition to the list of proven uses suggests ever-increasing applications under similar conditions.

For abrasion resistance at very low cost the sapphire-hard alumina has no parallel. Although a grit-blast pre-

* *Metallizing Equipment Co. Ltd.*



The ceramic coating on ballistic missile venturis is necessarily heaviest at the throat.

paration might be adequate for certain classes of work, the dense coatings used for extreme wear-resistance involve much higher internal stresses. It is therefore recommended that the coating be applied over a specially mechanically bonding thread, or on to the physio-chemical key provided by the patented Sprabond Wire process. The main advantages of the latter are that no tensile strength is removed from the base material, lower cost, it is speedy to apply and applicable on to hardened surfaces.

Pump plungers alumina sprayed on the packing areas are giving several times the original life. One company reported that severe scoring necessitated replacement within three months; there was no sign of wear upon inspection of the sprayed ceramic after eight months. The hard, dense, corrosion-resistant surface is frequently sealed with an air-drying phenolic resin. The sealer prevents contamination of both the base material and the alumina through the slight porosity. The possible removal of ceramic particles by impregnation of the pores by sand or other granular structures is thereby also prevented. Where the corrosive medium is primarily sulphuric or sulphurous acid, it is recommended that the coating be treated with a baked phenolic resin.

Another pump manufacturer sprays alumina to prevent erosion of the port-plates. In maintenance shops many times the original life of pump suction face plates, some handling a strong caustic solution as well as abrasive lime-sludge is said to be obtained by building up to the original dimensions with alumina.

A manufacturer of diesel engines, following extensive field tests, sprays a 0·010-in.-thick coating on the waterside of diesel liners. This has not only solved the problem of cavitation, but has also been found to be the most economical method. The ThermoSpray process is now incorporated into the production line on automatic jigs.

Molins Machine Co. Ltd. are the world's largest manufacturers of cigarette-making machinery. Fig. 2 shows some of the parts which are given a hard-wearing ceramic coat on production. The forming machine bed (A) has an endless belt running through the cavity to roll the paper and tobacco, thereby forming the cigarettes. A 0·040-in thickness of alumina is ground with a silicon carbide wheel to 0·030-in. thickness. The surface is then lapped with alumina sprayed rods and plates. The service life is at least equal to the previously-used tungsten carbide inserts, at one-tenth of the cost. Sprabond Wire is used to ensure an indivisible bond to base. Part (D) is the centre section of a coupling with tenons on each side; it is shown finish ground to limits and sealed. Parts (B) and (E) are shown before grinding or sealing. The alumina sprayed pad is applied on a true diameter, part (C), and then finish ground to limits, leaving the sprayed section standing proud. Part (F) is manufactured in three pieces to accommodate slot requirements, i.e. the inside corners must be sharp with a slot width of 9 mm. and a depth of $\frac{1}{4}$ in. This depth dimension necessitates the spraying, sealing and grinding of alumina edges of $\frac{1}{4}$ in. width.

Worm feeds, seal-rings, polishing jigs, chutes, impellers, conveyors and plug gauges are on the list of applications where erosion-resistant ceramic coatings are multiplying service life. The low cost and simplicity of deposition is a further encouragement to design engineers. It has to be borne in mind, however, that although ceramic sprayed surfaces will withstand exceptional abrasion, the granular structure of the coatings is not suitable for conditions involving severe point or line impact.

The dielectric features of sprayed ceramic are utilised when heater tubes, used in nuclear reactors, are insulated (electrically 5,000 volts) from the magnesium sheath in which they fit. Steel pins of welding jigs receive a 0·010-in.-thick alumina insulation which additionally resists the rough handling to which these parts are subjected.

Recently completed tests show very great promise for these ceramic coatings for corrosion protection where conditions are too severe for the cathodic protection afforded by zinc or aluminium wire metallising. In addition to the above-mentioned features, the coating in the "as-sprayed" condition provides excellent anchorage for nearly all kinds of organic top coats.

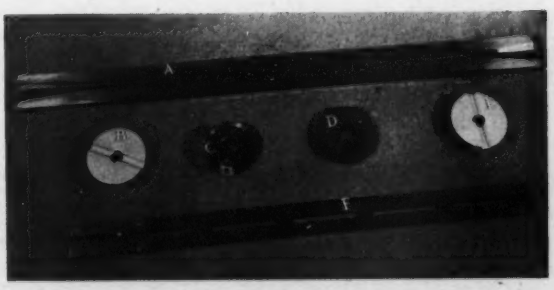
TABLE 1. General characteristics of sprayed ceramics

	Alumina	Zirconia
Melting point, °C.	2,050	2,535
Bulk density, gm./cc.	3·2—3·4	5·2—5·3
Porosity, %	6—10	6—10
Thermal expansion, °F. × 10^{-6}	4·3	6·4
Hardness, Mohs	9·0	8·0
Thermal conductivity,* (B.t.u./hr./ft.²/in./°F.)	19	8
Deposition, sq. ft./hr. (0·010 in. thick)	15	10
Colour	Grey	Tan brown

* On this same scale stainless steel (18–8) would read 185 and carbon steel 320.

TABLE 2. Type analysis of Metco Ceramic ThermoSpray powders

Ceramics	Aluminium Oxide	Titanium Oxide	Zirconium Oxide	Calcium Oxide	Silicon	Others
101	Balance	2·5	—	—	—	—
105	Chemically pure	—	—	—	—	—
201	0·5	—	93	5	0·35	Balance



These cigarette-making machinery parts, produced by Molins Machine Co., have been alumina-coated to give outstanding wear-resistance.

Some of the current applications cannot be classified under the headings of thermal barriers, abrasion resistants, anti-corrosive and dielectric coatings. A plastics manufacturer, for example, prevented the sticking of crimping jaws during the sealing operation with a 0·010-in. alumina deposit. The jaws, electrically heated, heat-seal various types of plastics bags and containers. Should the coating develop a layer of carbon in service, it can be quickly removed with a fine steel wire brush. The low coefficient of friction of sprayed ceramic makes possible the increased life of pump packings; the same feature is advantageously applied on conveyors—especially those carrying glass bottles.

Reference has been made above to the use of sprayed alumina to lap sprayed alumina. A large oil company found that with a ceramic coated plate they lapped wear-rings of gate-valves in 25 per cent of the original time and, using oil, saved half a can of lapping compound per valve.

Many special-purpose refractory and cermet (i.e., ceramic-metal mixes) powders may be sprayed, but alumina and zirconia are the materials most widely used.

The rapid advances over the past four years, considered alongside current development, promise considerable expansion in the immediate future. The imminent introduction of Plasma Arc Spray equipment, with operating temperatures of over 17,000 deg. C., is expected to result in the spraying of further high-melting point oxides and cermets, but optimum ceramic coatings are already available for industrial use.

The terms Metco, ThermoSpray and Sprabond are registered trade-marks of Metallizing Equipment Co. Ltd.

NIOBIUM HIGH TEMPERATURE ALLOYS

WHILE no single material will meet all of the requirements for high-performance missile and rocket power plants, gas turbine engines and nuclear power systems, some alloys now being studied show great potential for solving many engineering problems. A number of niobium alloy systems are being explored, and an alloy[1] consisting of 10 per cent titanium, 10 per cent molybdenum, with a balance of niobium, has exceptional properties compared with present known alloys in the temperature range of 1,100-1,430 deg. C.

The room temperature mechanical properties of Nb-10Ti-10Mo in the as-extruded condition are as follows:

Yield strength	92,000 p.s.i.
Tensile strength	100,000 p.s.i.
Reduction of area	47 per cent
Elongation	22 per cent
Hardness, B.H.N.	190
Charpy V-notch	6-8 ft. lb.

The hot hardness curve is quite flat to 980 deg. C.; and the hardness is reasonably high even at 1,400 deg. C. Creep-rupture tests on the Nb-10Ti-10Mo alloy were run at 1,430 deg. C., and at present no other known alloy has a strength level this high when tested in air without a protective coating.

MODULUS OF ELASTICITY—The modulus of elasticity was determined over the temperature range of 24-1,100 deg. C. from stress-strain curves, and drops from 16·5 at room temperature to $8{\cdot}5 \times 10^6$ at about 980 deg. C. Nb-10Ti-10Mo is not affected by thermal shock mainly because of its high thermal conductivity.

This niobium alloy shows two distinctly different oxidation effects when heated in air. The first is the formation of the usual oxide scale which results in loss of metal thickness (surface recession), and the other is the diffusion of oxygen in the metal, resulting in the formation of an oxygen-affected zone of increased hardness. This type of oxidation does not result in loss of metal thickness and the amount of subsurface-affected zone can only be measured metallographically.

TRANSITION TEMPERATURE—Niobium alloys have a ductile-to-brittle transition temperature similar to the other body-centred cubic metals such as tungsten, molybdenum, iron. The temperature for transition from ductile to brittle failure is lowered by cold work, slower speed of testing, increase in purity (especially the interstitial content) and conversely is raised by recrystallisation, higher speed of testing and increase in impurities. The transition temperatures for niobium and some binary alloys in the recrystallised state using the slow bend tests are below the boiling point of liquid nitrogen (−195 deg. C.). The Nb-10Ti-10Mo alloy in the cold-worked condition has a transition temperature for the slow bend test in the range of −72 to −184 deg. C. Transition temperatures for the recrystallised material in the tensile test are dependent on the interstitial level. The transition temperature has been lowered approximately 150 deg. C. by lowering the total interstitial level (carbon, oxygen, nitrogen and hydrogen) from 1,200 to 400 p.p.m. Work is in progress to determine the purity level required to lower the transition temperature to the point where this alloy can be welded and still be ductile at low temperature.

PREPARATION OF THE ALLOY—The Nb-10Ti-10Mo alloy is produced by double cold hearth melting in vacuum; the primary working of the ingot is accomplished by extrusion, and the metal then worked by forging, swaging or rolling to produce bar stock and sheet. After the original ingot breakdown, this alloy can be worked quite easily and should be amenable to all types of metal forming.

The Nb-10Ti-10Mo alloy is a solid solution not hardened for strength by the addition of a second phase and is not the most oxidation-resistant niobum alloy that can be produced, but was chosen to illustrate the base-line properties obtainable with niobium alloys.

The significant properties reported for it are as follows:

1. The alloy is quite soft and ductile at room temperature in the cold-worked condition.
2. The tensile strength in air at 1,100 deg. C. is 34,500 p.s.i.; at 1,415 deg. C., 11,000 p.s.i.
3. At 1,430 deg. C. in air 1 per cent creep takes place in 7½ min. at a stress of 5,000 p.s.i. and in 30 min. at 3,000 p.s.i.
4. The modulus of elasticity drops from 16,500,000 p.s.i. at room temperature to 8,500,000 p.s.i. at 1,100 deg. C.
5. For the temperature range of 1,100-1,370 deg. C. this alloy is not sensitive to thermal shock.
6. Nb-10Ti-10Mo is about five times as resistant to oxidation at high temperature as pure niobium and about 100 times as resistant as molybdenum, as measured by unit weight gain in 1 hr. Both an external oxide scale and an internal subscale are formed.
7. Nb-10Ti-10Mo has the ductile-brittle transition temperature characteristic of all body-centred cubic metals. As cold worked, the transition temperature is well below room temperature. As recrystallised, the transition temperature is slightly above room temperature at current purity levels.

REFERENCE

[1] *Technical Memorandum*. Du Pont de Nemours & Co. and Thompson Products Inc.

Fig. 1. Mark 2 aluminium ultrasonic soldering iron for aluminium made by Mullard Equipment Ltd.

NON-MECHANICAL JOINTING OF METALS

Lower fabrication and labour costs are possible in certain circumstances when using soldering, brazing or welding techniques for joining metals

by G. FITZGERALD-LEE, F.R.Econ.S., M.I.E.I., A.R.Ae.S.

THE principles of the three main forms of joining metals by non-mechanical means—soldering, brazing and welding—are generally well known and are defined in B.S. 499. The main advantages of the processes mentioned in this survey, which underlines the latest developments, over mechanical means of joining are that fabrication and labour costs are lower than by mechanical means and, as drilling, punching, reaming, bolting-up, riveting and folded seam joints (with their allowances required for extra metal and landings) are generally eliminated, the production rate is increased.

A welded design usually requires less material than mechanical means of joining, less even than soldering or brazing, thus lowering the weight and cost of the article; but all non-mechanical methods are comparatively easy ways of producing watertight joints and improved, smooth appearance. All of this results in saving material, time, weight and therefore money. There are, however, some metals which are difficult to join by fusion or even partial fusion, while others cannot be joined at all by such means, and in most of these cases it will be seen that several other non-mechanical means are applicable. In this survey, unless otherwise stated, the name of a metal includes also its alloys.

Soldering

Choice of solder depends largely on the joint strength required, resistance to corrosion, soldering method, type of joint and its size and thickness; the method depends on the equipment available, the quantities and shape of the product and the economic factors involved. Ordinary soft solders are covered by B.S. 219, but there are many solders—including silver solder (B.S. 1845)—and fluxes specific to various alloys. For all joining processes, the parts to be joined must first be as clean as possible, the function of a flux in soldering being to dissolve any oxide that happens to remain, but mainly to prevent further oxidation during the process. Certain acids and chlorides are more corrosive than activated resin fluxes, but they are useful when their residues can be completely removed after soldering.

Tests recently carried out by the Tin Research Institute show that a zinc chloride flux made up with polyethylene glycol has considerable advantages over the normal zinc chloride/water mixture. These advantages include much less spattering, better spread, since the polyethylene glycol is not volatile and continues to be operative during heating, and easier cleaning of residues.

Most forms of wrought iron, cast-iron, malleable cast iron and steel can be readily soldered, the main exceptions being certain alloy steels, but stainless steel can be soldered provided that the correct technique is carefully applied.

The first step is the preparation of the surfaces by removing all grease and dirt and by subsequent roughening. Small additions of glycerine to the flux will lower the surface tension sufficiently to allow the flux to wet thoroughly. A recommended solder is a 50:50 alloy of tin and lead, though for stronger joints 60:40 alloy or block tin may be used. It should be realised that, because stainless steel is relatively stiff compared to the solder, any subsequent deformation will result in rupture of the joint. Excess flux may be removed by sodium carbonate solution at 5-10 per cent concentration.

Aluminium is solderable provided that proper precautions are taken and that suitable protection is given to the joint. The ease of copper soldering varies according to the main alloy used—usually tin, zinc or aluminium. Nickel is easily soldered, but the soldering of magnesium, titanium and zinc (i.e., zinc alloys) is not yet advised.

A thin deposit of nickel, by the Kanigen[1] chemical process of nickel plating, on aluminium and its alloys considerably simplifies their soldering; the plating can also be used on stainless steels as a fluxless brazing material giving a good joint. This is particularly useful when the adherent oxide film on the steel causes difficulties in orthodox brazing.

Dip soldering is a simple and rapid process in which the fluxed surfaces are dipped into solder baths, and soldering can also be effected by torch, furnace (electric, gas or induction) and resistance methods as well as by means of a soldering iron. In order to effect the joining of some metals which could not normally be soldered, they can sometimes first be plated with solderable metals. The soft soldering of titanium, for example, is at present limited to techniques involving the electrochemical deposition of films of silver, copper or tin, from their fused salts, in an inert atmosphere, on to the titanium surface. These films can then be successfully soldered with conventional lead-tin solders, using non-corrosive fluxes.

Brazing

Flame brazing is a process in which the heat is obtained from a gas flame from a manually-operated blowpipe or torch. In furnace brazing, the heat is obtained by putting a complete workpiece into a furnace which may contain a protective atmosphere. Flux-dip brazing involves prelocating the brazing alloy, as in furnace brazing, the assembly being preheated and dipped into a bath of molten flux at a temperature above the melting point of the brazing alloy. In flow brazing the molten brazing alloy is poured into the joint. Other methods include resistance brazing, induction heating and block brazing.

The remarks concerning the soldering of ferrous metals also apply to their brazing. Pure aluminium, aluminium-1¼ per cent manganese and aluminium-magnesium-silicon (when the magnesium content is not more than 2 per cent) alloys can all be brazed. The brazing of copper varies as does its soldering, but nickel can be readily brazed. Titanium can be brazed, but with limitations, using chlorides of silver and copper as a flux, and the brazing of magnesium or zinc, like their soldering, is not yet advised.

As with soldering, brazing can be effected by torch, dip, furnace or resistance methods and also in a salt bath. High-temperature brazing involves unusually high melting point filler metals giving useful joint properties at high temperatures: some nickel alloys are thus joined in a furnace with an atmosphere of cracked ammonia or hydrogen, using a flux such as borax. Nickel and mild steel are examples of metals which can be brazed with copper, resulting in strength properties equal to those of the metals being joined.

Welding

Fusion welding is usually effected by means of a gas flame or by an arc welding method using a metal arc, carbon arc or an inert-gas, shielded arc; B.S. 499 gives the nomenclature, definitions and symbols used. In ferrous metals, welding usually becomes more difficult as the carbon content is increased—especially over 1 per cent. Cast iron—with 3-4 per cent of carbon—requires very special care, since the grades vary considerably and in the poorer qualities blow holes and inclusions greatly weaken any weld made. Also, care must be exercised to avoid further damage by thermal shock. Malleable iron, with 1-2 per cent of carbon, is also difficult to weld. Mild steel and wrought iron are generally excellent for welding and steel castings and nickel steels good. Martensitic stainless steels are readily welded but need post-welding heat treatment and air cooling; austenitic stainless steels are equally weldable and unless they are required for use in corrosive conditions they do not need post-welding heat treatment, but they are liable to weld decay. The weldability of alloy steels varies considerably. It is not yet advisable to attempt welding zinc.

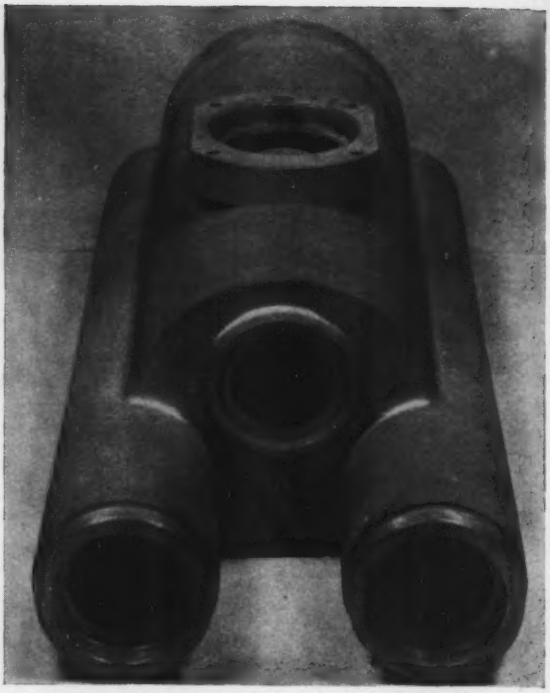


Fig. 2. Anode tube for X-ray machine welded with EutecRod 190 (Eutectic Welding Alloys Co.)

Gas Welding—The original and still most widely used gas welding method is the well-known oxy-acetylene process. Aluminium-magnesium alloys with more than 2½ per cent of magnesium are difficult to gas weld, otherwise the applicability of gas welding aluminium is as for the inert-gas, shielded arc method by which it is largely superseded. The weldability of copper (see also B.S. 1077) by gas varies from excellent, including pure copper, to "not advisable" (as in the cases of beryllium copper, tin bronze and gunmetals). Nickel is readily joined by gas welding, but this process for maganesium is almost out of use and it is not applicable to titanium. Filler rods for gas welding are covered by B.S. 1453.

Inert-gas, Shielded Arc Welding—This is usually effected by either the tungsten-argon (or helium or nitrogen) arc method, or by the consumable electrode method, the former being the more widely used. It has the advantage of requiring no flux and can be effected very rapidly. B.S. 638 refers to electric arc welding plant and equipment, B.S. 2901 to filler rods and wires and B.S. 709 describes methods of testing welds.

In the tungsten-argon arc process the arc burns within a shroud of argon; as this inert-gas shield excludes the arc and welding zone from the atmosphere, oxidation and the formation of nitrides are prevented. The arc is struck between a tungsten electrode and the work and burns within the argon shroud; when filler metal is required, a filler rod is used as in oxy-acetylene welding, the arc taking the place of the gas flame. Consumable-electrode welding, in which a filler wire is used in place of the tungsten electrode, is a development of the tungsten-argon arc process.

Excellent welds are obtained by the inert-gas, shielded arc method in pure aluminium or aluminium-1¼ per cent manganese, aluminium-magnesium and aluminium-magnesium-silicon alloys; the method is also suitable for copper and titanium in particular, and nickel. Good welds are obtained in magnesium by the tungsten-argon arc method, but the consumable-electrode technique for magnesium has not yet been developed. In the Aircomatic[2] process, instead

of argon, helium or nitrogen being used as the shielding gas, carbon dioxide is used instead, with reverse-polarity d.c. It is used mainly for mild and low alloy steels.

METAL ARC WELDING—As defined by the B.S.I., metal arc welding is "arc welding with a metal electrode, the melting of which provides the filler metal"; B.S. 639 refers to covered electrodes for the metal arc welding of mild steel, B.S. 782 to electrodes for metal arc welding in the construction of ships, B.S. 938 to metal arc welding as applied to tubular steel structural members. B.S. 1719 is a classification of covered electrodes for the metal arc welding of mild steel and medium-high-tensile steels of welding quality and B.S. 1856 gives general requirements for the metal arc welding of mild steel. In that the arc is struck between the metal electrode and the work, it is similar to inert-gas, shielded arc welding, but in metal arc welding consolidation necessitates the use of a flux. Copper is readily welded by this means but the method is not yet widely used for the metal. It has been superseded by inert-gas, shielded arc welding for aluminium and nickel and is not applicable to magnesium or titanium.

CARBON ARC WELDING—In this process the arc is struck between a carbon rod and the work, d.c. supply being used, with the work positive. The remarks above for metal arc welding apply also to this method for all metals.

RESISTANCE WELDING—This is a form of pressure welding in which the heat to cause fusion of the metals is produced by the welding current flowing through the contact resistance between the two surfaces to be welded, these being held together under mechanical pressure. In slow butt welding the parts are in contact, end to end, under a steady pressure. Flash butt welding is similar to slow butt welding, but the pressure is light initially until the welding temperature is reached, when a heavy upset pressure is applied. In spot welding the parts are overlapped and gripped between the tips of two electrodes. In seam welding the parts are again overlapped, but gripped between circular electrode wheels or between a bar and a wheel. For projection welding the current flow, heating and pressure are localised by means of projections on one or both parts. Cross-wire welding is a form of projection welding used for making wire products.

Aluminium, magnesium (except when the parts are required for heavy-duty work), nickel and titanium are easily joined by spot welding, as well as copper and most of its alloys, although some cannot be welded by this means. Seam welding is normally continuous, but if it is intermittent it becomes "stitch welding", the intermittent welds being made by switching the current on and off while the rollers are driven continuously along the seam. Although copper and nickel can be satisfactorily seam welded, and it is excellent for titanium, aluminium welding is difficult by this means and it is not yet advised for magnesium. For high-speed welding and freedom from distortion, a resistance welding process for producing butt-type joints between flat strips or sheets, known as "foil seam welding", is used, foil being applied to both the top and bottom surfaces over the butt joint. Flash welding is applicable to titanium, aluminium and the aluminium alloys mentioned under tungsten-argon arc welding above. It is applicable to copper and most of its alloys, especially brasses but not to bronzes, and also to nickel, but for magnesium it is not yet advised.

In "high-frequency resistance welding" HF electrical energy is used to effect the heating necessary for welding; alternating current of 100,000 c/s or more is applied by contact electrodes directly to the work. Copper, stainless steel, silicon bronze and nickel alloys can be joined by this method, and also titanium, provided an inert gas is used for shielding. Successful welds can be made over large contact areas by small-capacity machines if "percussion welding" is used. In this process the weld is made very quickly over a large area by means of either a rapid discharge from a stored electrical energy power source or dissipation of a.c.

Other Welding Methods

The cold pressure welding process was developed in 1946 and produces homogeneous welds at room temperature solely by pressure. No heat, flux or post-weld cleaning is needed and the process can be effected by semi-skilled operators. The process is applicable to most of the common non-ferrous metals and their alloys, but to aluminium in particular.

In this process, as the pressure is applied, the abutting surfaces are sealed from the atmosphere. Increased pressure then causes the metal in the joint area to flow, disrupting any contaminating films and oxide layers and finally creating intimate contact at atomic distances, forming true welds with continuous grain structures.

Manual twin-arc welding is a method by which two electrodes giving two arcs are used in a special manual electrode holder; it is used in a similar manner to a single arc, but gives greatly increased welding speed. Automatic metal-arc welding machines are used for all classes of tank and boiler welding, any application, in fact, in which long seams have to be welded. Submerged-arc welding (the Unionmelt[3] process) may be either automatic or manual, the arc being struck between a bare wire and the parent plate. The arc, electrode end and molten pool are submerged or enveloped in a finely-divided granulated powder which turns to a slag in its lower layers under the heat of the arc. An adaptation of this is automatic submerged twin-arc welding, in which two arcs are used instead of one.

Magnetic force set up by the welding current is used in "magnetic force welding", a technique in which accurate synchronisation of the electrode force and the welding current is obtained. The magnetic force spot welding machine is of direct-acting ram design, modified to take electro-magnets for the application of pressure. The process

TABLE 1. Principal suppliers of aluminium solders

SOFT SOLDERS
Enthoven Solders Ltd. (Enthoven AS10, AS20).
Grey & Marten Ltd. (Amalgam AL 1, 2 and 3).
Tiltman Langley Ltd. (TL solder IP).
Fry's Metal Foundries Ltd. (Fry's LM, Fryal).
Perdeck Solder Products (Epatam A66, A67).

SOFT SOLDERS FOR ELECTRICAL CABLE JOINTING
W. T. Glover & Co. Ltd. (Alglo).
Fry's Metal Foundries Ltd. (Alca P).
Grey & Marten Ltd. (Amalgam AL 4 and 9).
Johnson & Phillips Ltd. (T.C.Z.).

HARD SOLDERS
Sheffield Smelting Co. Ltd. (Thesscal A and P 12).
Metal & Plastic Compacts Ltd. (MPC).

SOLDER PAINTS
Perdeck Solder Products Ltd. (Epatam 3311, Mk. 1).
Fry's Metal Foundries Ltd. (Fryolux A20).

TABLE 2. Principal suppliers of aluminium fluxes

FLUXES FOR SOFT SOLDERS
I.C.I. Metals Division and Fry's Metal Foundries Ltd. "Kynal": zinc-depositing flux in an organic base. Reacts at 280 deg. C. Residues are non-corrosive.

Enthoven Solders Ltd. "Enthoven": organic-base flux in liquid or paste form. Also available as flux cored solder (see Table 1). Operates up to 300 deg. C. Residues non-corrosive.

FLUXES FOR ELECTRICAL CABLE JOINTING
Johnson & Phillips Ltd. "Junal 5": tin-depositing reaction-type flux. Used with flame or resistance heating. Various fluxes operate between 250 and 350 deg. C. Residues corrosive, but joints are always protected. Fluxes are used with filling solders.

Sheffield Smelting Co. Ltd. "Thesscal R1": as for Junal 5 above.

W. T. Glover & Co. Ltd. "Alglo": organic-base flux reacting at 215 deg. C. Residues non-corrosive.

I.C.I. Metals Division and Fry's Metal Foundries Ltd. "Kynal": as for "Alglo" above.

FLUXES FOR HARD SOLDERS
Sheffield Smelting Co. Ltd. "Thesscal 92": chloride-base flux in liquid or paste form. Operates at approx. 400 deg. C. Residues corrosive.

TABLE 3. Silver solder and high-temperature brazing materials for nickel alloys.

Type of Silver Solder or High-Temperature Brazing Alloy	Melting Range deg. C	Brazing Methods applicable	Type of Flux required	Typical Furnace Brazing Temp. (deg. C) and Conditions	Remarks
Silver-Copper-Zinc BS.1845 – Type 4	690–735	All usual methods	Proprietary	750 – Reducing atmosphere and flux	Applicable to all alloys but corrosive or high-temperature conditions limit useful service
Silver-Palladium-Manganese (30% Pd)	980–1130	Torch, Salt Bath, Furnace	Borax	1140 – Reducing atmosphere and flux	Used for high-temperature materials only
Silver-Palladium-Manganese (35% Pd)	1130–1190	Salt Bath, Furnace	Borax	1225 – Reducing atmosphere and flux	Used for high-temperature materials only
Palladium-Silver-Aluminium (60% Pd)	970–1040	Torch, Furnace	Borax	1120 – Reducing atmosphere and flux (Flux may not be necessary with pure, dry hydrogen)	Used for high-temperature materials only
Nickel-Chromium Boron-Silicon	1010–1070	Furnace	Borax	1150 – Dry hydrogen (flux may not be necessary with Nimonic 80 or Nimonic 90)	Used for high-temperature materials only
Manganese-Nickel-Chromium	1050–1070	Torch, Salt Bath, Furnace	Proprietary	1150 – Reducing atmosphere and flux	Used for high-temperature materials only

Data by Henry Wiggin & Co. Ltd.

is useful for welding high-conductivity metals together and to carbon steels; some metals which were previously considered to be unweldable can be joined by this means.

Friction welding is a form of pressure welding which depends on heat produced by the friction of parts moving rapidly in contact under high pressure, the resultant heat being sufficient to effect fusion and bonding of the metals. Ferrous metals, aluminium and titanium have been welded by this means as well as copper to ferrous metals. At the present stage of development of the process it is applicable only when at least one of the parts to be joined is cylindrical and can be rotated.

If a 6 or 8 S.W.G. mild-steel electrode with the normal extruded coating is laid flat along a piece of steel plate and the end connected to the electrode holder, the arc struck between the electrode end and the plate will continue burning steadily all along its length, producing a neat, regular welding bead. This is the principle of "firecracker welding", which has special application in joints where access is difficult for welding manually.

In atomic hydrogen arc welding an a.c. arc is maintained between two tungsten electrodes. Hydrogen is fed into this arc, and the energy of the arc, together with the action of the tungsten electrodes, splits up or dissociates the molecules of hydrogen into atoms. The atoms recombine when they reach the slightly cooler regions outside the arc and the heat liberated by this recombination results in temperatures of up to 4,000 deg. C. being attained. Thermo-pressure welding is a type of solid phase welding which depends on the cleanliness of the surfaces held under pressure and the application of heat in order to obtain a true pressure weld. By this means it is possible to weld metals to semiconductors or other metals which would be difficult by a fusion process.

Thermit is the name given to a mixture of finely-divided iron oxide and powdered aluminium. If this mixture is placed in a fireclay crucible and ignited by means of a special powder giving off great heat, the action, once started, continues throughout the mass of the mixture. The aluminium is a strong reducing agent and combines with the oxygen from the iron oxide, the iron oxide being reduced to iron. The intense heat which results, because of the chemical action, not only melts the iron but raises it to about 3,000 deg. C., the aluminium oxide floating to the top of the molten metal as slag. The crucible is then tapped and the superheated metal runs around the parts to be welded, which are contained in a mould. The high temperature of the iron results in excellent fusion taking place with the parts to be welded, which completes the thermit welding.

In bronze welding (B.S. 1724), especially applicable to copper, and as distinct from autogenous welding, the melting point of the filler metal is lower than that of the materials to be joined, but the technique is similar. The main advantage of bronze welding over true welding is that, as in low-temperature welding, the parent metal is only wetted or tinned, and never fused, so that thin parts can be joined without backing strips and without the danger of melting them sufficiently for holes to be formed.

The Fusarc and Fusarc/CO_2 processes[4] are methods of automatic arc welding with a continuous covered electrode, enabling long periods of uninterrupted welding to be carried out. In deep penetration welding, the joints are made by fusing together a considerable amount of base metal with a little filler metal, which is achieved by high heat input. Heat in the arc is the product of arc voltage and welding current, and the welding current is limited by the current-carrying capacity of the core wire of the electrode. Therefore, the large amount of heat required for deep penetration welding is obtained by increasing the arc voltage of the electrode, usually by the use of some cellulosic material in the covering. This method of welding is fast, it saves the cost of bevelling plates for butt welding and makes perfect joints.

In stud welding, the "stud" is slipped into the chuck of a special gun and held against the plate joint. In one common type of tool for this process, when the trigger is pressed a current of 10-15 amp. passes through an iron-cored choke which causes the main contactor to close and the conical end of the stud to be drawn a predetermined distance from the plate. A low-intensity or pilot arc is formed, upon which the welding arc is superimposed as soon as the main contactor is closed. A pre-set timer controls the duration of the welding arc, which is extinguished when the molten end of the stud is returned firmly, but gently, to the pool in the plate. The main contactor opens and the flow of current ceases. By this means, rods, tubes, hooks, split and ordinary pins can be welded in the same manner as studs. Brass and copper studs can be welded to steel plate and to thin copper sheet, especially good results can be obtained with complex aluminium bronze and silicon bronze. This process is advantageous when welding M.S. studs to stainless steel vessels as penetration of the shell is avoided.

Sifbronze[5] welding is a comparatively low-temperature method of joining most ferrous and non-ferrous metals, except aluminium, by means of gas. The process involves raising the temperature of the joint faces locally to a dull red heat, using a neutral flame; the end of the filler rod is heated and coated with a tinning flux (the Sifbronze Process 101, for cast iron, is described here as an example of the method). After preheating, the joint is tinned and built up with the torch flame, rod and flux, resulting in joints with strengths of up to 40 t.s.i.

A few years ago it was found that metals could be welded by means of elastic vibratory energy introduced into the joint area, which has now led to ultrasonic welding. This is a solid-state bonding process which is usually effected at low temperature and without the aid of solder or flux. The metals to be joined are placed between two welding tips or "sonotrodes" clamped under low static pressure, and ultrasonic energy is introduced through one of the sonotrodes for a few seconds. Interfacial activity, apparently induced by the elastic vibratory energy, ruptures existent coatings and produces bare metal contact, effecting

a metallurgical bond. Aluminium can easily be welded by this means, at room temperature, and copper, brass and gilding metal are also thus weldabie; limited success has been achieved in Alclad, nickel, magnesium, titanium and thin stainless steel.

Intermolecular jointing is also effected at room temperature and involves the physical properties of the oxide film on metals. The metals easiest welded by this means are those with a high rate of surface film hardness, such as aluminium, which so far seems to be the best metal for the process at room temperature, others having inferior welding properties and low hardness ratios, thus usually necessitating the use of heat. By this means, copper can be welded in hydrogen at 250 deg. C. and, with more deformation, copper, iron, nickel and zinc at room temperature; magnesium cannot be thus welded at room temperature, but it can be joined at heat. To effect welding, aluminium is cleaned with a fine steel wire brush (other metals with a coarse wire brush), brushing at a speed of 2,000 ft./min. for aluminium and 1,600 ft./min. for other metals, to roughen the surface without undue heating. The surfaces are then put together, placed in a press and pressure is applied for about 10 sec. Half-hard aluminium sheet needs from 20-50 t.s.i. and annealed aluminium sheet from 15-45 t.s.i.

Diffusion bonding is a process in which metals are heated to temperatures below their solidus points and held under pressure for some time, without a liquid phase being formed; the bonding is effected by the movement of atoms or intermetallic compounds across the interface of the surfaces in contact. The process is at present limited to joining gold to copper, silver, aluminium and nickel, and nickel to iron and copper. The "low heat input process" of Eutectic Welding Alloys Co. minimises distortion, warping and internal stresses that result when conventional welding or brazing processes are used and it permits considerable savings in time and materials. The process depends on the principle of surface alloying; the base metal is not melted, but it is dissolved by, and surface alloys with, the low melting point filler metal. The minimum temperature to which the parent metal must be heated at the surface in order to obtain the bond or surface alloying with the filler metal is the bonding temperature which for ferrous metals varies from about 200-400 deg. C. only, the filler rods or electrodes and fluxes being specific to the process. By this means most ferrous and non-ferrous metals can be joined by welds with tensile strengths of up to 50 t.s.i.

For welding really heavy sections—up to 1 ft. or more in thickness—electro-slag welding has been devised. Fusion of the electrode wire and the base metal is effected in and under molten slag covering the metal from which the weld is formed, the electrode wire being immersed in slag.

Chemically active materials with high melting points can be melted in a furnace by using electron bombardment in a high vacuum, which results in very pure metals with properties not attainable by any other method. To effect such electron beam welding, in the machine with a vacuum of less than 10^{-4} mm. Hg., the tungsten filament of the electron gun projects electrons at a high voltage to the work which is at earth potential and mounted on a turntable beneath the stationary electron gun. The beam is electrostatically or magnetically focused so that controlled, high-intensity, localised heating occurs at the joint to be welded at the electron spot diameter required. While the joint is moved slowly through the electron spot, welding is effected. This process is at present largely confined to tungsten, tantalum, zirconium and beryllium, but is also being applied to aluminium, magnesium and titanium.

In arc plasma heating temperatures of up to 17,000 deg. C. are attained. An inert gas (or nitrogen or hydrogen) passes through a chamber in which an arc is maintained; the gas is ionised by the flow of electrons from cathode to anode, the resulting bombardment causing the gas to be heated to the extremely high temperatures mentioned. Any material that is heated to such temperature and which is in the ionised condition is termed "plasma"; plasma-forming gas is fed into the torch nozzle inlet, a H.F. arc is struck, causing the gas to emerge as a plasma flame of high temperature. It is more a heating than welding method, but makes possible the joining of metals of high melting points which are difficult or impossible to weld by other means.

Considerable progress is being made in the field of dip welding or "dip transfer welding", the general idea of which is rather similar to dip soldering or brazing, with the object of bringing the work to the molten weld metal instead of vice versa.

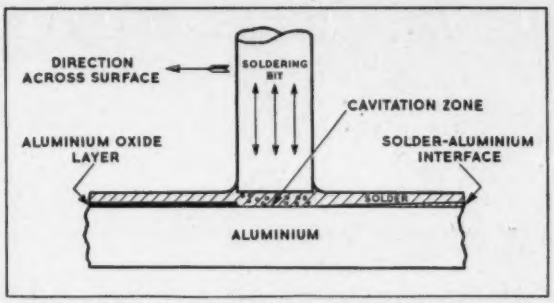


Fig. 3. Ultrasonic soldering. Action of ultrasonic vibrations during soldering.

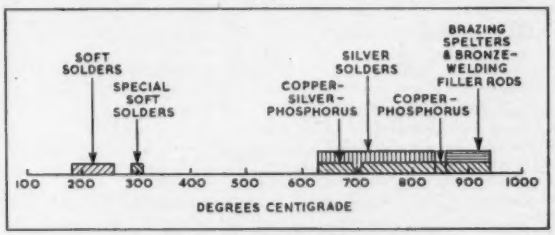


Fig. 4. Melting ranges of jointing materials.

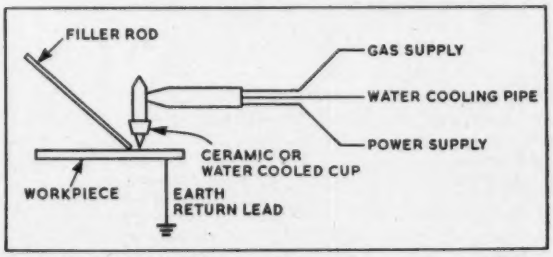


Fig. 5. Schematic diagram of tungsten argon-arc welding plant.

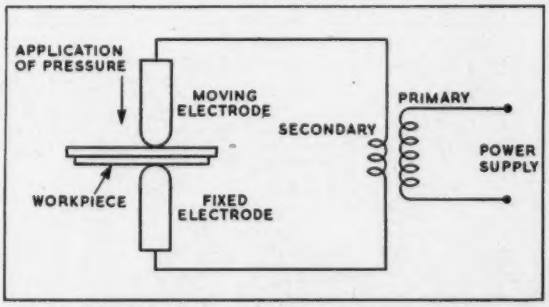


Fig. 6. Schematic diagram showing principles of resistance welding.

Joining Dissimilar Metals

Copper can be resistance-welded to most metals and

TABLE 4. Welding techniques for various metals

Description	Purpose	Process	Flux	Approx. Melting pt. or range, °C.
Copper				
Copper wire	Welding copper	Oxy-acetylene Argon arc, I.G.S.M.A. and nitrogen arc	Boric acid type None	1,073–1078 1,083
Phosphor Bronze				
Phosphor bronze (Cu-Sn) 95/5 92½/7½	—	Oxy-acetylene Argon arc and I.G.S.M.A.	Boric acid type None	890–1,050 850–1,030
Aluminium Bronze				
Aluminium bronze	Welding aluminium bronze Surfacing Steel	Argon arc and I.G.S.M.A.	None	1,045–1,050
Al. bronze to ASTM B171, Alloy D	Welding Alloy D	,,	,,	1,060–1,080
Al. bronze to ASTM B171, Alloy E. composite wire depositing aluminium bronze to this spec.	Welding aluminium bronze Surfacing Steel	I.G.S.M.A. only	,,	1,035–1,055
Aluminium Alloy (Wrought Al. and alloy wire to B.S. 1475)				
GIA	Welding aluminium 1A, 1B			660
GIB	Welding aluminium 1B, 1C			660
GIC	,,			650
NG3	Welding alloy N3			620–650
NG21	Welding alloys H9, H30			565–630
NG4	Welding alloys N4, N5, N6, H30	Oxy-acetylene, Argon arc and I.G.S.M.A.	None for Argon arc and I.G.S.M.A. For oxy-acetylene, flux to DTD 119 or B.S. 1126	630–650
NG5	,,			610–645
NG6	,,			570–640
HG9, HG30	Welding alloys H9, H30			620–650
Brass				
Arsenical 70/30 brass	Welding alpha brasses (except aluminium brass)	Oxy-acetylene Argon arc	Boric acid type None	920–955
Manganese bronze	Welding manganese bronze. Bronze welding C.I.	Oxy-acetylene	Boric acid type	890–904
Silicon brass	Welding brass	Oxy-acetylene	Boric acid type	880–890
Aluminium brass	Welding aluminium brass	Argon arc	None	950–890
Nickel-silver	Welding nickel silver	Oxy-acetylene Argon arc	Boric acid type None	1,050–1,100
Titanium				
Commercially pure	Welding titanium	Argon arc	None	1,660
Titanium alloy (5% Al, 2½% Sn)	Welding Ti alloys (5% Al., 2½% Sn)	Argon arc	None	1,590

I.G.S.M.A.—Inert gas shielded metal arc –

TABLE 5. Joining methods and their applications.

Method	Iron	Aluminium	Copper	Nickel	Magnesium	Titanium
Soldering.	All except certain alloy steels.	All good, with proper precautions and suitable protection to the joint.	Excellent - to - good according to main alloy: Sn, Zn, Al, etc.	Most good, with certain reservations.	*	*
Brazing.	As above.	Good: Al, Al-1½% Mn., Al-Mg-Si alloys when Mg. content is not more than 2%.	As above.	As above.	*	Good, with limitations.
Gas welding.	ALL PROCESSES. Excellent: mild steel, wrought iron.	As for inert-gas shielded-arc welding and largely superseded by it. Al-Mg with more than 2½% Mg. difficult to gas weld.	Excellent-to-not advised (e.g. Be-Cu, tin bronze, gunmetals).	All weldable except those with high titanium and aluminium.	Obsolescent.	Not applicable.
Tungsten - argon arc welding.		Excellent: Al, Al-1½% Mn, Al-Mg, Al-Mg-Si.	Excellent-to-good.	Very good.	Very good: most.	Excellent.
Consumable electrode welding.	Good: steel castings, nickel steels, martensitic and austenitic stainless steels.	As above.	As above.	As above.	*	As above.
Metalarc welding.		Superseded by I.G.S.M.A.	Excellent-to-good, but not applied widely in engineering.	All weldable.	Not applicable.	Not applicable.
Carbonarc welding.	Difficult: cast iron, malleable iron.	Obsolescent.	Good, but as above.	Superseded by metalarc welding.	As above.	As above.
Spot welding.		Good: all.	Mostly good, but some not advised.	Very good.	Very good, but not for heavy duty work.	Excellent.
Seam welding.	Very good to unweldable: alloy steels.	All difficult.	Good.	As above.	*	As above.
Flash and butt welding.		Good for alloys mentioned under tungsten-argon arc welding.	Mostly good, especially bronzes, but brasses not advised.	As above.	As above.	As above.

Zinc alloys: Gas welding good for zinc die casting repairs; remainder not advised yet.

**Experimental technique; not necessarily available commercially.*

alloys which are themselves amenable to the process; for example, phosphor bronze, copper or bronze can be welded to steel, brass to phosphor bronze or silver and even copper to aluminium (although such welds are likely to be brittle). Copper can be joined to most ferrous metals by bronze welding, but the bronze welding of aluminium has not so far succeeded. Brazing and soldering are particularly suitable for joining dissimilar metals; copper can be joined to many metals by brazing and even to aluminium—provided the copper has been tinned and an aluminium-silicon alloy is used as filler. Soldering has the same applications as far as copper is concerned, a chloride-fluoride flux being used with a tin-zinc solder. The silver soldering of steel to aluminium-bearing copper alloys needs a short brazing cycle or the use of a brazing alloy containing nickel, or the interposition of a copper shim. A particularly interesting case is that of the brazing of copper to nickel-iron or cobalt-nickel-iron components in thermionic valves; the filler material contains 70 per cent copper and 30 per cent gold. With coated and plated metals, resistance welding often becomes, in fact, resistance brazing, for an alloy bond appears to be formed between the filler material and the metals being welded when copper is joined to cadmium, nickel, silver or tin.

By means of the metallic arc process, nickel and dissimilar nickel alloys can be welded to one another and to mild or austenitic stainless steels—with certain reservations, including weld compositions; these metals can also be welded together by means of the oxy-acetylene and argon arc processes.

Aluminium can be soldered to steel, brass or copper by first tinning the surfaces to be joined and then sweating or soldering them together, with preferably an 80/20 tin-zinc or similar good solder, but in order to prevent galvanic corrosion all such joints should be protected with lacquer, paint, plastics or bitumen. When adhesive bonding, mentioned later, is not applicable, aluminium can be brazed to other metals, especially mild steel; but the brazing of aluminium to copper, brass, Monel, cast iron, stainless steel and other alloys containing chromium is difficult, and aluminium cannot be usefully brazed to magnesium. New methods of welding aluminium to steel by the Argonaut[6] process have now been developed in which no melting of the steel takes place. Using a 5 per cent silicon aluminium alloy rod, the bond relies on a semi-brazed capillary action taking place between the coated surface of the steel and the adjacent light alloy plate.

Titanium is often brazed to aluminium in the manufacture of anodising jigs, using an aluminium-silicon filler rod and brazing as quickly as possible, and joints of high strength are obtained with resistance brazing, using brazing alloy shims of silver, silver solder or aluminium. Titanium can be soldered to other metals by first depositing silver, copper or tin on to its surface as described above. Ferrous metals can be joined to others in the same way as the metals above, and the low-temperature welding process is applicable to the joining of most dissimilar metals, including ferrous to non-ferrous.

Other Methods

CHEMICAL JOINTS—Ferrous metals can be joined chemically to aluminium by the Al-Fin process, the joint consisting of an iron-aluminium alloy composition approximating to $FeAl_3$. Such joining can be effected only during the fabrication of a bimetallic component and not between finished articles. A cast-iron cylinder liner, for example, is prepared and then immersed in molten alloy until the aluminium has attacked the iron and the bond has been effected. The liner is then placed in the die and the casting metal poured in, forming the extended fin section. While the molten metal is rising in the mould, it is drawn up by the molten interface material on the surface of the iron liner forming a meniscus similar to that between water and the wet side of a glass, for which reason the liner is described as being "wetted". Any oxide formed on the melted surface by contact with the air is peeled off by the rising metal and floats to the surface of the casting, leaving a perfect, clean, intermetallic bond between the alloy and the cast-iron liner. Being an intermetallic compound, the bond is brittle, with an average thickness of 0·001 in. and tensile strength up to 8 t.s.i.

CASTING ON—Aluminium can also be bonded to iron by "casting on", a process in which aluminised iron or aluminium inserts are first chilled and then reheated to a temperature at which the aluminium coating becomes viscous, thus promoting intimate bonding as soon as casting begins, without oxidation of the underlying iron. The iron parts so treated are then laid in the mould and the aluminium poured around them. The process is still in its infancy and rather defective; but in view of the progress of present work it appears to have a promising future when fully developed.

TABLE 6. Physical properties of plastic metals (Devcon Corp.)

	Plastic Steel	Heat Resistant	Aluminium Putty	Wear Resistant
Ult. compression strength, p.s.i.	18,000	30,000	20,000	16,000
Ult. tensile strength, p.s.i. ...	10,000	9,000	8,500	8,000
Mod. of elasticity in tension, p.s.i.	850,000	$1{\cdot}2 \times 10^6$	—	$1{\cdot}3 \times 10^6$
Flexural strength, p.s.i.	13,000	19,000	11,000	11,000
Izod impact strength, ft. lb./in. of notch	1	0·08	1·2	0·8
Rockwell hardness	93	97	93	93
Machinability	Excellent	Excellent	Excellent	Poor
Lin. coeff. of thermal expansion, cm./cm./°C.	25×10^{-6}	45×10^{-6}	—	—
Thermal conductivity, cal./cm./s./°C.	0·00125	0·00233	0·00271	—
Specific gravity	2·5	1·8	1·8	1·8

Plastic steel consists of 80 per cent steel and 20 per cent plastic, a composition which effects joints without heat or pressure; as its tensile strength, at the present stage of development, is only 5 t.s.i., it is not for use in stressed parts, but it makes joints in most metals, and between any two, including steel, iron, aluminium, brass, bronze or lead, that can be sawn, drilled, tapped, threaded or ground with ordinary equipment. Another "plastic" product supplied by the same firm, E. P. Barrus Ltd., is aluminium putty, an 80 per cent aluminium and 20 per cent plastic composition giving a tensile strength of 4 t.s.i. Both products have excellent machinability and in each case the hardening is chemically accelerated to complete its work within 2 hr. of the joint being made. In the same series of plastic metals are Devcon WR, a wear-resistant material with the same uses as above, and Devcon C, a heat-resistant material which can be used continuously at 200 deg. C. or intermittently at 260 deg. C.

In recent years a very great increase has taken place in the use of epoxy resins and other thermosetting compounds for joining metals. Joints in aluminium by these means are exceptionally good and those in magnesium are usually adequate for all but highly stressed applications. Among several firms who are specialising in this method are CIBA (A.R.L.) Ltd., which, as Aero Research Ltd., developed Redux during the war, a metal-to-metal bond using heat and pressure. The most recent of such products is Araldite.

REFERENCES

1. Albright & Wilson Mfg. Ltd. (Kanigen).
2. Air Reduction Co. (Aircomatic).
3. Quasic Arc Ltd. (Unionmelt).
4. Quasi Arc Ltd. (Fusarc).
5. Suffolk Iron Foundry Ltd. (Sifbronze).
6. British Oxygen Gases Ltd. (Argonaut).
7. Wellworthy Ltd. (Al-Fin).
8. Devon Corp. (Devcon).
9. A.S.T.M. Special Tech. Pub. 189.

DESIGNING WITH WORK-HARDENED SHEET METAL

by H. A. JAHNLE*

WITH a knowledge of metallurgy a designer can more fully exploit the advantages of cold-worked sheet in metal fabrications. The rolling hardens the metal while squeezing it into thin sheet and increases yield strength and ultimate tensile strength, the U.T.S. of some steel being tripled in this way. The drawback is the reduction in ductility. This apparent brittleness of the rolled metal and its softening and annealing with heat have combined to limit its usefulness.

However, weld joints can actually be 90 per cent as strong as the parent metal; and some of the rolled materials will work well at moderately high temperatures without showing excessive creep or bringing up the limitations given by lowered ruptured strength.

In general, metals with a face-centre cubic structure have good work-hardened properties. Examples are austenitic stainless steels, nickel-base alloys and cobalt-base alloys; austenitic stainless is the most popular work-hardened material for high-strength parts. From an annealed ultimate tensile of less than 100,000 p.s.i., strengths up to 300,000 p.s.i. can be developed. The newest steels have surpassed 350,000 p.s.i. by a combination of work hardening, transformation and precipitation.

Special materials have also shown promising work-hardened properties for elevated temperature or lightweight applications. Many of the tests to determine the cold-rolling and strain-ageing capabilities of the material can also be used to decide forming and fabrication steps of the sheet-metal parts during later stages of production.

Phenomena such as preferred orientation, given by the cold rolling, explain directional properties in the sheet, and generally rolling raises both ultimate and yield strength, ultimate more in the direction of rolling, and yield more in the transverse direction. Ductility, both in bending and in tensile elongation, is less in the transverse direction. The modulus of elasticity, parallel to rolling, is lowered as much as 10 per cent, while compressive properties are better in the transverse direction. Physical properties such as thermal coefficient of expansion will also change with the direction, but whether they go up or down depends upon the material. When material is cross-rolled—in directions perpendicular to each other—it has more uniform properties, but cross-rolled sheet is not available in the continuous coil lengths desired for high-speed production.

Cold working does straighten out the elastic portion of the stress-strain curve, enabling the elastic limit and yield stress to be determined with greater accuracy. Where the metal can be age-hardened after cold working, its yield and ultimate strength both go still higher and anisotropy (directional properties) goes down. Also, ductility and residual stresses are reduced.

BEHAVIOUR AT ELEVATED TEMPERATURES—Cold-worked properties of metals show up better in creep-ruptured tests when service temperatures are under the recrystallisation range. Below this range the 1,000-hour stress-to-rupture strength will usually be greater than the 0·2 per cent yield strength. For certain alloys this generalisation does not always hold true, so specific applications require plotting the high-temperature properties to compare the long- and short-time disadvantages of cold working. Above the recrystallisation range, the creep-rupture properties are usually inferior to those obtained by heat treatment. Again, exact properties and performance will vary: the more the cold work, the lower the recrystallisation range; the longer the time at elevated temperature, the more complete loss of work-hardening benefits.

* *The Budd Co., U.S.A.*

Fabrication

Because ductility varies with the direction of cold rolling, fabrication technique should vary accordingly. Elastic spring-back is greater in the direction of higher yield strength, and minimum-bend radii should be determined for both directions of rolling the sheet. One necessary precaution is that laboratory bend-radii be given some margin of safety to avoid fractures during actual shop forming and bending. For maximum formability, ageing—which lowers ductility—should be done after forming and, if necessary, parts to be aged can be clamped to avoid distortion, but usually temperatures are not high enough during ageing to give serious warping. Another effect of bending is that it may severely change the mechanical properties at these points.

JOINING BY WELDING—Arc-welded joints can result, in certain configurations, in weld strengths up to 95 per cent the strength of the parent, hardened metal, and a study of this should include evaluating the weld strength in various gauge thicknesses of the work-hardened material while varying the width of the weld zone. The geometry or shape of the joint, and particularly its alignment to the direction of stress, are also important in determining the end-result. Final evaluation is best made on the completed structure.

Although the welding process anneals the metal locally, the hardened material adjacent to the weld zone retards the reduction in cross-section of the annealed metal. The stress distribution thus developed actually increases the apparent strength of the annealed metal in the weld. For example, if a standard tensile specimen of metal hardened to 250,000 p.s.i. were annealed locally in a narrow band across the width to its fully annealed strength of 75,000 p.s.i., the specimen would fail in the annealed zone, but at a value closer to 150,000 p.s.i. than 75,000 p.s.i. Similarly, arc-welding two work-hardened specimens would give strength at the joint greater than that of the weld-annealed material.

For spot welding, optimum nugget diameter is four times the sheet thickness. This is the size where, for equal thickness of sheet, the shear area of the weld nugget equals the shear area in the sheet around the nugget. This holds true for sheet from 0·03 to 0·06 in. thick. The weld pattern can be developed for optimum joint efficiency by performing the weld-joint studies similar to the arc-welding studies above. Spot welds in specific materials should be tested in tensile shear and direct tension to determine placement and loading of the welds in a structure.

In comparison with metals which are heat-treated to similar strengths, spot welds in cold-worked sheet are more ductile and therefore have less effect on concentrating stresses. This allows design with cold-worked metal at a higher strength than heat-treated steels, and parts can have higher stress levels, with resultant greater reliability in service.

Strain-Ageing Benefits

In many alloys, ageing or precipitation-hardening will not occur to any extent without prolonged heating time. Sometimes cold working can induce this precipitation, and strengthening therefore occurs within practical heat-treat times. When the precipitation temperatures are below the recrystallisation temperature, these strain-ageing effects will give added strength to the material. There is a corresponding loss in ductility, but for complex structures this method of hardening imparts extra hardness and strength with relatively low ageing temperatures. In some alloys extremely high strengths can be obtained—often unattainable by other strengthening methods.

we hardly recognise ourselves

The various guises our tubes appear in after they leave us are—to say the least—numerous. The list of industries, let alone products, in which they play a part is almost as wide as Industry itself. A few samples: Refrigeration; Electrical and Allied Industries; Radio and Electronics; General Engineering. In products just let's say Ellay Small Diameter non-ferrous tubing are found everywhere small metal tubing is used.

Our output of small aluminium tubes includes:—

Tubes from 3/64″ to ⅝″ o. d.
From 3/32″ to 20 ft. lengths
From 0·006 to 0·064 wall thickness
In general purpose, close or precision tolerances
In super purity, commercial purity or alloys

We also supply tubes in copper and brass, and precision tubular parts in non-ferrous metals to your specification.

Everyone has a use for

ELLAY Tubes LTD.

ELLAY TUBES LIMITED

COX GREEN WORKS, MAIDENHEAD, BERKS. TEL: MAIDENHEAD 3303

A.P. 30

Aluminium nitride whiskers (Al-N)—sublime at 2,000 deg. C. (×100.)

STRENGTH FROM WHISKERS

THE ultimate goal in the improvement of structural materials has been the achievement of the strength available from atomic cohesion. At present, most efforts to strengthen structural materials follow the metallurgical approach (alloying, additives, heat-treating, working, etc.) to gain higher strengths in metals. But the highest strengths developed by these means are still a small fraction of the strength theoretically obtainable from the flawless cohesion of atoms in a metal.

However, it is known that fine crystal filaments, commonly called "whiskers", have demonstrated the highest strengths known in materials, in some instances approaching the theoretical limit of atomic cohesion.

Tube Investments' Research Laboratories at Hinxton Hall have carried out a research programme into the strength of non-metallic whiskers to ascertain why weakness arises and how to achieve consistency of properties.

TABLE 1. Tensile stress of some of the strongest whiskers

Material	Mod. of Elast. p.s.i.	U.T.S. p.s.i.	Stress/Modulus Ratio
Silicon	23,000,000	550,000	1/42
Carbon	150,000,000*	3,000,000	1/50
Iron	29,000,000	1,900,000	1/15
Silver	11,000,000	240,000	1/46
Copper	18,000,000	430,000	1/42
Quartz	11,000,000	600,000	1/18
Sapphire	74,000,000	1,700,000	1/43

* With the exception of carbon, the modulus of which is measured along S_{11} crystallographic axis, the remainder tend to indicate an inflated strain value.

TABLE 2. Weight reductions possible with whisker composites in tension structures

Component or Application	Structural Weight	
	Whisker	Conventional
Cables and rods	1	10–20
Removable plates and sheets	1	1·5–3
Pressure vessels, tanks, fuselage	1	7
Miscellaneous:		
Porous sheet transpiration cooling	1	10
Prestressing cables for ceramics	1	8
Rocket motor cases, exhaust cones	1	5
Tubing, ducts, cabin walls	1	8
Centrifugally tensioned components	1	4

Similar work has been carried out by the Plessey Co. and A.E.I. (Aldermaston) and by the Rand Corp. in the U.S.A., General Motors Corp. and several other companies. Soviet investigations appear to be following the same lines, most of their published literature being translations of those appearing in the West.

The properties of whiskers and the structural characteristics of hypothetical materials composed from them permit comparing the weights of tension structures made from whiskers with the weights of structures made from conventional materials. Reductions to one-fifth of the conventional weight appear to be feasible, assuming that whiskers could be mass produced in usable forms.

Table 1, which lists the highest stresses measured in certain whiskers, shows that the actual ultimate stress is in fact of the order predicted by theory.

However, not all whiskers are strong, as only about 1 per cent of those at present grown give the very high strength values, and small whiskers of diameters of about 1·0μ are stronger than those with diameters to approximately 50μ.

Small metal whiskers (about 1·0μ) behave elastically, td fracture at high elastic strains. With increasing whisker diameter, a plastic range appears in the stress-strain curve and metal whiskers give curious effects to low flow stress once having gone beyond their elastic limit.

The modulus of elasticity of a whisker may differ radically from the modulus of large polycrystalline amounts of the same material and can range from a halving to a doubling of the polycrystalline modulus of metals, and for carbon may range up to a factor of 150×. This effect results from the fairly uniform orientation of the crystal axis in whiskers.

Very little accurate measurement has been made of creep, although it has not been observed in whiskers below the normal recrystallisation temperature, implying considerable strength retention at elevated temperatures, even close to the melting point.

It is most probable that whiskers of Si-C or Al_2O_3 may find an earlier practical application than the metallic whiskers, since these latter are subjected to oxidation, become ductile, easily corroded and have comparatively low melting points.

Fibred-composite materials will find use mostly in structural components designed by tension criteria, and much less use in other components designed by, say, buckling criteria.

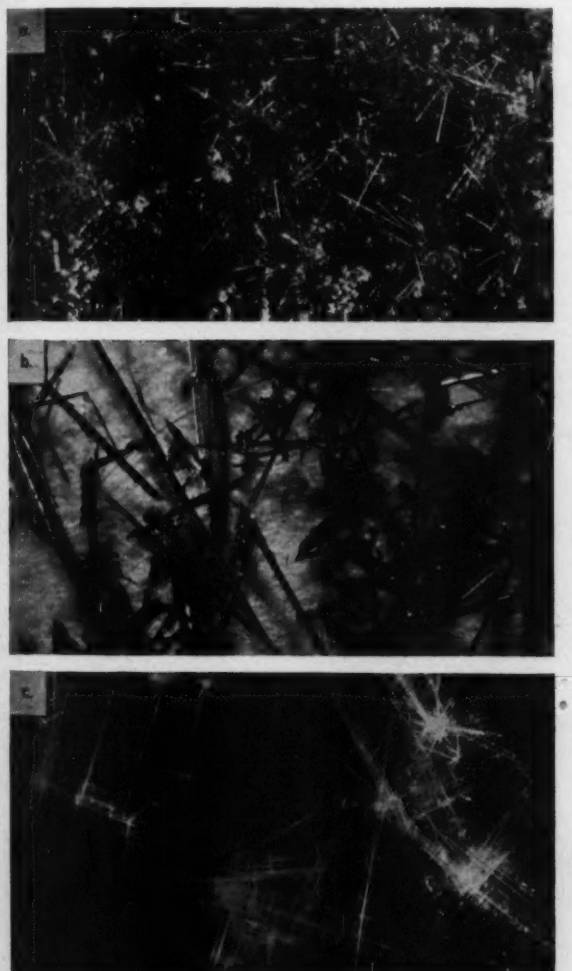
The comparison of whisker materials at elevated temperatures is based upon the assumption that strength deteriorates slowly at first, then rapidly between the softening or recrystallisation and the melting temperatures. The soften-

ing or recrystallisation temperature for metals and ceramics is roughly proportional to the melting temperature.

Therefore, it is sufficient to know only the density, modulus and melting temperature and some simple assumption as to the modulus decrease with temperature, to derive theoretically the relative weight of equal-strength whiskers of various materials at various temperatures.

Weight estimates of typical tension structural elements should include not only the basic material properties but also any features peculiar to the materials under comparison. For example, sheets of conventional materials require doublers wherever the edges are fastened, and this doubler weight should be accounted for, even though it is only a small fraction of the total weight. The problem of fastening to adjacent structure will be far more severe for whisker composite materials, with a proportionally larger weight penalty in most instances.

Extra weight of this kind was included in an overall design comparison of such structural components as cables, biaxially stressed sheets fastened so as to be removable (as in some pressurised vessels), biaxially stressed and permanently fastened sheets (as in spherical vessels and some cylindrical tanks) and components in miscellaneous applications. The results, which are summarised in Table 2, show that, on the average, the weight of tension components in future structures might be reduced to one-fifth of their present weight if whisker composites were available, and were substituted on an equal-strength basis.



(a) Silicon carbide whiskers (SiC)—sublime at 2,000 deg. C. (×50.)

(b) Silicon whiskers (melting point 1,420 deg. C.) grown by the reduction of $SiCl_4$ with zinc vapour. (×50.)

(c) Sodium chloride whiskers grown from aqueous solution. (×5.)

(Photos: T.I. Research Laboratories)

If whiskers are to be exploited structurally, it should be first established that no insurmountable obstacles exist to their production in the needed quantities, qualities and forms, and it has been assumed that any of the growing techniques successfully demonstrated in the laboratory can be scaled up to pilot-plant production and eventually to full-scale production, with sufficient economic incentives.

Several techniques have been used in laboratories to grow whiskers:

CHEMICAL REDUCTION OF METAL HALIDES—Reduction of metal chlorides, iodides or bromides by means of the passage of hydrogen or the presence of a reducing agent (such as zinc) can result in the growth of filamentary crystals.

ELECTROLYTIC DEPOSITION—Silver, iron and copper whiskers have been grown by electrolytic deposition from a molten salt of these metals.

VAPOUR DEPOSITION—A controlled supersaturation of the vapours of metals and their compounds usually can be made to precipitate whiskers of these materials.

HIGH STRESS—When soft metals are under high stress, whiskers tend to grow from the bulk of the metal. The whiskers grow probably from their bases (not from their tips) in this situation. These were the first type historically observed to have high strength in such metals as tin, cadmium, lead, zinc and others.

DRAWN MICRON-SIZE FILAMENTS—Considerable strength (though not as great as that of whiskers) has been exhibited by hot-drawn metal filaments, and by fibres of compounds (such as glass and silica) drawn from their liquid phase.

Alignment, thinness and length of whiskers could be controlled by the proper saturations, temperatures and magnetic or electrostatic fields, the cutting and collecting being done by vibratory or mechanical scraping techniques.

The whiskers may be envisaged in bundles or mats, held together by friction and electrostatic forces barely sufficient to prevent unravelling. Spinning of fine strands of whiskers from these agglomerates should be similar to the spinning of textile or glass fibres, and these strands could then be woven into cables, sheets or vessels.

However, it must be remembered that it is difficult to grow whiskers long enough to achieve this, and strong whiskers are very susceptible to surface damage; the larger the whisker, the greater the possibility of flaws occurring.

This woven product, still weak in tension because of the lack of a good shear bond between adjacent fibres, could be brought into its final, strong form by at least two processes that can raise the cohesive bond between whiskers: impregnation with a binder after weaving, or precoating the strands with a binder previous to weaving, either method followed by thermal cure of the shell. The choice of a suitable binder is nevertheless another difficult problem to be solved.

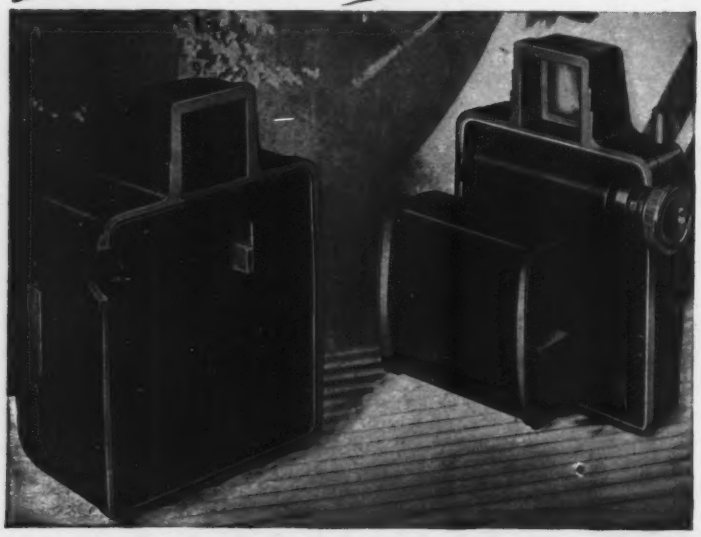
Plastics-impregnated fibred glass is a good example of the processes of imparting good cohesion to filament aggregates by either method. Currently, plastics such as phenolics, silicones, polyesters, etc., are in general use as cohesive binder materials, and experiments have been made with fibres in a metal matrix. Plastic resins can be used at present only up to approximately 300 deg. C., but there are hopes that future developments, for example, boron polymer resins, will extend their usefulness hopefully to 550 or 650 deg. C.

"Future Possibilities in Fibred Materials", G. A. Hoffman (Rand Corp.), 6th Sagamore Conf., 1959.

"Observations on the Effect of Surface and Structure on the Tensile Strength of Iron Whiskers", WADC Technical Report 58-369.

EMD 2715 for further information

Focus on economy



The rapid expansion of the photographic market has been accompanied by an ever increasing demand for a low-cost camera capable of taking photographs usually associated with more expensive models. To meet this demand the Vista 12 was designed. It is another excellent example of how much can be produced for how little, when designer and plastic moulder work closely together.

The Vista 12 incorporates an eye-level viewfinder and precision optically ground glass lens system. It is synchronised for flash, takes a standard 120 film and produces excellent colour shots in bright sunlight. It retails at about £1.1.0d.

Whether you wish to sell to mass markets at budget prices or to more exclusive markets —we have the plant, experience and technical resources to meet your needs.

Six high impact, camera black, polystyrene mouldings and three chromium plated die castings are incorporated in the camera which when complete separates into two sections for loading and unloading. Our subsidiary, the British Optical Lens Co., designed and supplied the lens and viewfinder systems—incorporating optically ground glass lenses. The complete production from tools to assembly and packaging was handled by us.

E. Elliott Limited

the plastic moulders
with the engineering background

315 Summer Lane Birmingham 19
Telephone: Aston Cross 1156/7/8/9

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Electronic Energetics

Soviet scientists are working on the development of a new branch of science known as electronic energetics; a recent report suggests that new possibilities exist for concentrating energy, making use of semiconductors in an apparatus with which temperatures could be stabilised in small spaces. Such a climate-regulating device releases heat if the air in the room is cold and takes heat from the space if the temperature is higher than permissible. During experiments it was discovered that a phenomenon of energy concentration existed which would seem to prove the hypothesis of Friedrich Engels, that in some way the heat being radiated out into space could be reconcentrated.

The circuit in the equipment in question is made up of several types of material and it is probable that at the place where two types of material meet—in the boundary layers —the electrons of the flowing current are accelerated. The accelerating electrons cause the formation of the heat surplus, and the energy necessary for this is "pumped" out of the space surrounding the system of electric conduits by the electrons. Thus, the observed phenomenon does not contradict the principle of the conservation of energy; rather, it offers a new method for accumulating or concentrating thermal energy.

Soviet engineers feel that electronic energetics may finally offer a more abundant energy source than even atomic energy.

German Nuclear Power Station

The first nuclear power station being built in the German Federal Republic will initially have a relatively low net electrical output of 15,000 kW. It is an experimental plant to gain experience in the construction and operation of atomic power stations. The reactor works by the boiling-water method, and operates with indirect circulation, i.e., the turbines are not driven by the primary steam generated in the reactor but are fed with secondary steam produced in the interposed heat exchangers.

Natural circulation is sufficient with the required reactor output; this means that the water heated, but not evaporated in the reactor core, does not need to be circulated artificially. If the operating results are favourable, it is intended roughly to double the output of the power station in a second construction stage. This would be done by increasing the throughput of coolant by forced circulation and by the erection of a second turbo set.

The primary steam production is 118 short tons/hour at a pressure of 72·3 atmospheres and temperature of 286 dec. C., producing secondary steam production of 105 short tons/hour at a pressure of 47·7 atmospheres and a temperature of 258 deg. C. The turbine is an AEG saturated steam turbine turning at 3,000 r.p.m., giving a maximum output of 16,000 kW. The reactor boiler is a cylindrical vessel 2·5 × 8·3 m. high made from plated steel 104·5 mm. thick, the fuel being UO_2 with 2·6 and 2·3 per cent U^{235} in eighty-eight elements of thirty-six fuel bars each.

Control of the reaction is by twenty-one hollow boron steel bars introduced pneumatically from below.

Polishing and Deburring Metal Parts

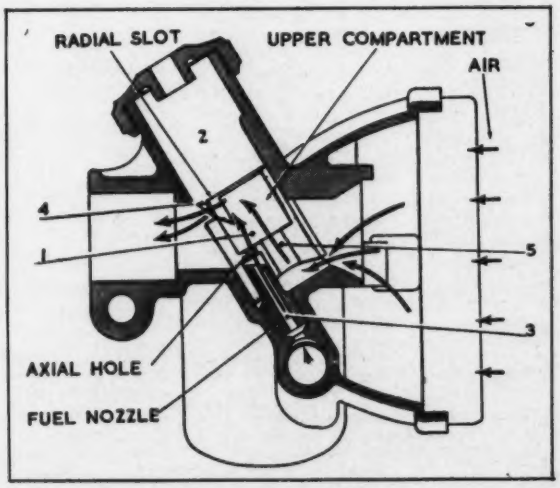
A new method of polishing and deburring mass produced metal parts has been developed in Switzerland by Hans Oetiker Co. It is called the Rotol process, and is said to use mineral grains of extreme hardness together with specially-developed chemicals in a rotating drum. Polishing grains are sized from 2-40 mm. For treating extremely complex metal parts, grains smaller than 2 mm. are used additionally.

Instead of needing a different chemical for each metal being treated, only two distinctly different chemicals are used. They are not easily confused. These chemicals serve for degreasing, derusting, deburring and polishing. An additional chemical will protect metal parts from rusting after treatment.

Carburettor with Automatic Choke

A new automatic choke developed in the Netherlands is designed for use in the type of carburettor usually fitted to small autocycle engines. The normal travel of the throttle slide is extended beyond the closed position so that it aligns with an additional choke opening (4) on the upper part of the slide at the engine side opposite the induction manifold.

Since the choke opening is larger than the aperture (5) on the air entry side, a high vacuum is produced in the mixing chamber (2) which induces injection of fuel through the starting jet (1) which opens directly above the atomiser (3), thus obtaining the correct mixture for starting. When the motor is sufficiently warm, it is run at full throttle, which causes the petrol valve to unlock the starting plunger, thus cutting off the supply of petrol to the starting jet. Manufacturers are Eerste Nederlandse Carburateurfabrick de N.V.



This Dutch-designed carburettor is fitted with an automatic choke.

New Books

Specification and Management of Materials in Industry. *By C. H. Starr.* (*Thames & Hudson, 21s.*)

THIS book deals with a management aspect of industry that has so far received scant attention.

In dealing with the problems of materials engineering, the book brings this science to its correct perspective and emphasis. The author adequately demonstrates the need for materials engineering as an entity and gives some basic principles for organisation in this direction. Thereafter, the book enlarges upon methods and routines for practical application. The extent to which the new science interlocks with other executive activities is considered in detail and given practical consideration: the author gives concrete examples of the final and total application of his techniques in case study examples.

This book is a challenge to conventional industrial management and very clearly demonstrates a major lack in industrial organisation generally. While present tendencies for advancement in management techniques generally take abstruse forms, the author shows clearly that straightforward thought and common-sense appreciation still have further application in industrial management.

S.A.B.

Nature and Properties of Engineering Materials. *By Z. Jastrzebski.* (*Chapman & Hall, 88s.*)

In today's design problems the importance of the correct selection of materials cannot be over-emphasised, and it is more than ever necessary that the designer should be familiar with the nature of materials, and this book is one of the few that can be recommended without fear of the practical aspect being overwhelmed with pure scientific data.

The arrangement of the contents is to be commended, the first section dealing with the structure of matter, followed by colloids and organic high polymers. The section on mechanical properties includes plasticity and flow, radiation damage and the relation of properties to strength. Metals, ceramics and related materials are each separately considered, with further sections on electrical, magnetic and thermal properties, corrosion, friction, wear and lubrication. The book concludes with cementing materials and concrete, and a section on protective materials, which includes metallic coatings, chemical conversions, organic and ceramic coatings.

Nomography. *By A. S. Levens. 2nd Ed.* (*Chapman & Hall, 68s.*)

Engineers and designers are today finding increasing benefits from using nomographs in repeated interpretation of mathematical formulæ. This book emphasises the geometric method in the development of the basic theory, and in this edition are three new chapters dealing with circular nomograms, projective transformations, and the relationship between Cartesian and alignment nomograms with applications to experimental data. A method of designing nomograms with four variables without the need for a reference axis is included, together with information on the use of curved scales with straight-line scales. The appendix contains some 58 examples which are widely applicable.

Elements of Material Science. *By L. H. Van Vlack.* (*Addison-Wesley, 49s.*)

The introductory test is aimed for the engineering students with a background knowledge of general physics and chemistry. The contents cover three major fields: to orient the student in the study of engineering materials and its related terminology, to acquaint him with atomic structures, crystals and phases upon which the grosser structure and properties depend, and to assist in the study of the behaviour of materials in service under conditions involving mechanical stresses, thermal reactions, corrosion, electro-magnetic fields and radiation.

The book is well illustrated and includes at the end of each chapter examples upon which the student can work.

Hyperstatic Structures. *By J. A. L. Matheson. Vol. 1.* (*Butterworth, 90s.*)

The practical interpretation of theories relating to statically indeterminate structures is always a source of irritation to the designer, and this book is significant in that the author has attempted, with success, to integrate and relate the many various theorems, so that the user may have a clear idea of their limitation and applicability.

Castigliano's theorems are developed to some length in an early section of the book, subsequent sections dealing with general theorems and methods for linear elastic structures. Moving loads, frames with rigid joints, arches and the stability of struts and frameworks are adequately covered and expressed, the final section dealing with matrix algebra and its application to the various problems associated with the indeterminate structures which may thus be more conveniently solved by this method in conjunction with a computer.

Applied Heat for Engineers. *By J. B. O. Sneedon. Third edition.* (*Blackie, 25s.*)

This book seems remarkable value for its price. The physical properties of heat and their application to heat engines are clearly and concisely given in an easy-to-digest style for students trying to achieve the first part of the B.Sc. course.

Various chapters are concerned with heat and matter which includes gases, liquid and solid state, plasticity and surface tension; pressure and its measurement and thermometry; specific heat and aspects of heat and expansion; change of state, fuels and combustion and mechanical equivalents. The laws of thermodynamics and the classic cycles are amply covered and of special interest are the final chapters which deal with more specific applications. These cover steam plants, compressors, gas turbines and refrigerators. A useful appendix and concise index concludes an excellent text-book on a complex subject.

Angus Gear Book. (*George Angus & Co., 15s. Students 7s. 6d.*)

Technical reference books on gears have rarely shown in a simple straightforward manner the factors relating to gears and gear cutting, so it is refreshing to find this involved subject treated so factually and concisely in this book. Tooth forms, methods of calculation, loadings and choice of materials are all covered. Here is a valuable text-book for students and a reference book *par excellence* for designers.

Specifications for Springs and Spring Materials. (*Coil Spring Federation Research Organisation, 25s. 6d.*)

This book includes all the relevant B.S., D.T.D. and service specifications relating to springs, and covers both material and methods of calculation. One page worthy of special reference is the comparison of British E.N. spring steel with the American S.A.E. equivalents. Engineers will find this a useful, compact, reference book.

LETTER TO THE EDITOR

Sir,

A member has brought to my notice the article "Where to Find Technical Information" in your March issue, which is without doubt a most useful collation by your staff. It is disappointing to us to note that no reference whatsoever is made to the National Association of Drop Forgers and Stampers, from whom technical information on the design, production and uses for forgings can always be obtained. We should be grateful if the forging industry can be included if you should compile a similar list in the future.

Technical officer, **G. H. Jackson**

N.A.D.F.S.,
Grove Hill House,
245 Grove Lane,
Handsworth,
Birmingham, 20.

We regret it was not possible to include every organisation in the survey, but we hope to revise and bring this information up to date from time to time and to include additional organisations of value to designers.

STRUCTURAL HARDWOODS

Available in the U.K.

Engineering Materials and Design

DATA SHEET No. 36

NAME	DENSITY 12% M.C. lb./cu. ft.	ULTIMATE STRESS			ELASTIC MODULUS 10^3 p.s.i.	NATURAL DURABILITY	RESISTANCE TO IMPREGNATION	WOODWORKING PROPERTIES		BENDING PROPERTIES R/S
		Bending p.s.i.	Compression p.s.i.	Shear p.s.i.				Resistance in cutting	Blunting effect	
Abura	34	11,500	6,490		1,440	Non	Moderate	Medium	Moderate (occ. severe)	48
Afara/limba	31	7,200	5,240	1,280	1,230	Non	Moderate	Medium	Mild	
African walnut	34	11,300	6,730	1,280	1,430	Moderately	Extreme	Medium	Mild	
Afrormosia/kokrodua	46	18,400	9,970	1,950	1,930	Very	Extreme	Medium	Moderate	52
Afzelia	45	15,900	8,920	1,950	2,060	Very	Extreme	High	Moderate	76
Agba						Durable	Resistant	Medium	Moderate	35
(Belgian Congo)	30	10,200	5,310	1,410	1,070					
(Nigeria)	32	12,610	6,240	1,530	1,240					
Beech (Italian)	42	14,850	7,230	1,890	1,570	Perishable	Permeable	Medium (variable)	Moderate (variable)	35
Birch (Canadian yellow)	43	17,200	8,880	2,130	2,270	Perishable	Moderate	Medium	Moderate	40
Camphorwood (E. African)	38	13,300	7,650	1,920	1,550	Very	Extreme	Medium	Mild	55
Gedu (Nohor)	35	10,600	6,310	1,610	1,330	Moderately	Extreme	Medium	Moderate	65
Guarea	39	14,700	8,360	1,730	1,680	Durable	Extreme	Medium	Moderate	63
Gurgon	46	15,900	8,330	1,560	2,260	Moderately	Resistant	Medium (variable)	Moderate (occ. severe)	
Idigbo	29	12,000	6,320	1,600	1,400	Durable	Extreme	Medium (variable)	Mild	60
Iroko/Mvule	39	11,900	6,950	1,710	1,360	Very	Extreme	Medium	Fairly severe	
Kapur/Bornean camphorwood	49	18,700	10,100	1,670	2,900	Very	Extreme	Medium (variable)	Moderate (occ. severe)	
Keruing	50	18,800	10,580	1,400	3,110	Moderately	Resistant	Medium (variable)	Moderate (occ. severe)	
Mahogany (African)	31	10,700	5,680	1,340	1,480	Moderately	Extreme	Medium (variable)	Moderate (variable)	48
Makore	44	12,900	6,220		1,420	Very	Extreme	Medium	Severe	49
Mansonia	40	16,800	8,190	1,980	1,690	Very	Extreme	Medium	Moderate	34
Maple (rock)	46	17,200	8,320	2,460	2,200	Non	Resistant	High	Moderate	40
Meranti, red	32	11,800	6,680	990	1,820	Moderately to durable	Resistant or extreme	Medium (variable)	Moderate (occ. severe)	Not suitable
Mora	62	23,100	12,240	2,560	2,970	Durable	Extreme	High	Fairly severe	76
Muninga	35	13,200	7,280	1,620	1,200	Very	Resistant	Medium	Moderate	55
Niangon/nyankom	-	12,370	7,220	1,610	1,470	Moderately	Extreme	Medium	Moderate	59
Oak (American white)	42	15,200	7,440	2,000	1,780	Durable	Extreme	Medium (variable)	Moderate (variable)	43
Oak (European)	43	13,300	7,210	1,760	1,560	Durable	Extreme	Medium (variable)	Moderate (variable)	46
Obeche	24	8,400	4,190	990	900	Non	Resistant	Very low	Mild	38
Opepe	47	16,500	10,020	2,190	2,070	Very	Moderate	Medium	Moderate	
Ramin	41	18,430	10,110	1,490	2,170	Non	Permeable	Medium	Moderate	72
Sapele	40	9,500	8,320		1,450	Moderately	Resistant	Medium	Moderate	50
Seraya (white)	33	11,800	7,190	1,030	1,790	Non	Resistant or extreme	Medium	Mild	Not suitable
Tasmanian oak	42	15,900	9,700	1,750	2,360	Moderately	Resistant	Medium (variable)	Moderate	55
Teak	43	14,300	8,320	1,350	1,850	Very	Extreme	Medium	Fairly severe (variable)	55
Utile	40	14,200	8,440	2,160	1,670	Durable	Extreme	Medium	Moderate	66

NOTES

1. Where alternative names are current, these are given thus: Afara/limba.
2. **Ultimate Bending Stress.** Equivalent fibre stress at maximum load of small clear specimens at 12 per cent moisture content.
3. **Ultimate Compression and Shear Strength.** Parallel to the grain of small clear specimens of 12 per cent moisture content.
4. **Elastic Modulus in Bending.** Small clear specimens at 12 per cent moisture content.
5. **Natural Durability.** Refers to resistance of the timber to fungal decay. Each timber has been put into the category of (a) very durable, (b) durable, (c) moderately durable, (d) non-durable, (e) perishable.
6. **Resistance to Impregnation.** Indicates ease of impregnation with preservatives. Categories (a) permeable—can be penetrated completely under pressure without difficulty; open tank process will also give heavy impregnation. (b) Moderately resistant—fairly easy to treat under pressure. (c) Resistant—difficult to treat under pressure. (d) Extremely resistant—absorb very little preservative even under long pressure treatment.
7. **Bending Properties.** The most important factor in assessing the bending properties of a timber is the minimum radius of curvature that can be obtained with a certain percentage of success. For structural laminated work, timber will generally be bent cold in the form of thin laminæ. The ratio R/S, where R is the radius and S is the thickness of the wood, has been determined by test, at a moisture content of 12 per cent, as the ratio at which breakages during bending do not exceed 5 per cent.

Data by Timber Development Association

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians. Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipe-work is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

SEND FOR BROCHURE No. X57

Made under licence from the Solar Aircraft Co., California U.S.A.

TEDDINGTON BELLOWS

EXPANSION JOINTS

TEDDINGTON AIRCRAFT CONTROLS LTD. (*Industrial Bellows Division*)
Ammanford, Carmarthenshire. Tel.: Ammanford 2255

TORQUE-HORSEPOWER-SPEED CALCULATIONS

Engineering Materials and Design
DATA SHEET No. 37

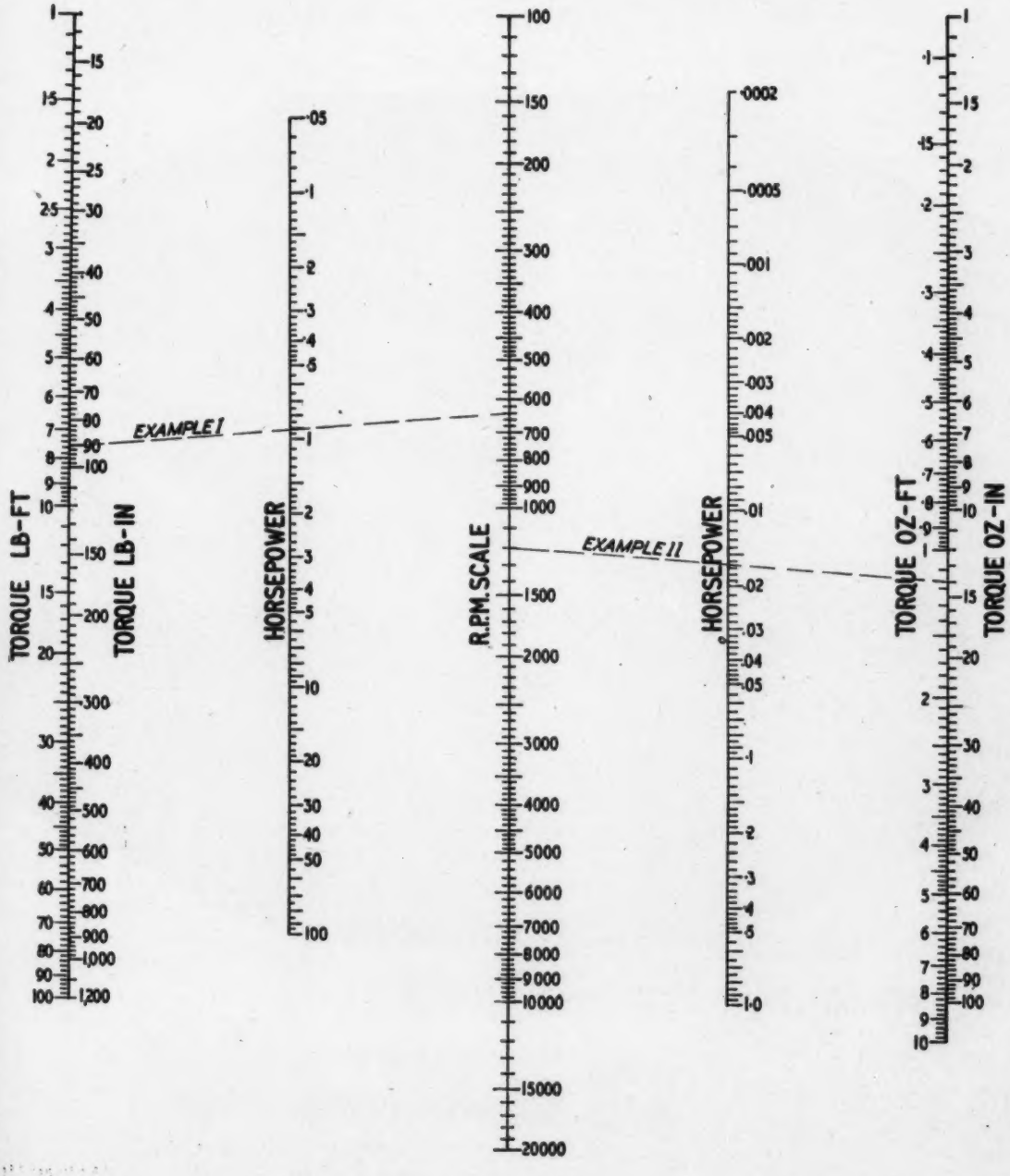
To extend the range of the nomogram outside the scale values, use 1/10 of the r.p.m. value as a scale value and multiply the resulting h.p. scale value obtained by 10 and so on.

Example 1. Given measured torque is 90 lb. in. at 640 r.p.m., determine the horsepower transmitted or delivered. Answer: 0·92 h.p.

Example 2. Given torque to be transmitted is 14 oz. in. at 12,000 r.p.m., determine the h.p. transmitted.

Use 12,000 ÷ 10 = 1,200 as the r.p.m. scale reading and solve.

Answer: 0·0167. Multiply by 10. Final answer: 0·167 h.p.



Data sheet by R. H. Warring

EMD 2719 for further information

M.E.L make Magnesium —and History

Most things magnesium in this country—
from alloy to finished article—
owe much to the technical knowledge,
practical skill and manufacturing facilities
of the Company which pioneered and promoted
the metal in Britain; Magnesium Elektron Limited.
In fostering the idea of ultra-lightness,
and transforming it into an engineering fact,
M.E.L have won for magnesium a firm place
in the history of British industry.
They offer their unique experience, now as in the past,
to all metal-using industries where lightness,
strength and economy of working
are matters of great importance.

you buy more than metal from M.E.L

M E L

Magnesium Elektron Limited

Clifton Junction Manchester. Tel. Swinton 2511
London Office: 5 Charles II St. St. James's SW1. Tel. TRAfalgar 1646
Magnesium Elektron, Inc., New York 20, USA

WHAT'S NEW IN MATERIALS & COMPONENTS

Metallised Polyester Tape

Speedfix metallised polyester film tape, type MP1, is supplied in 72-yd. rolls and is manufactured from a clear polyester film which has been coated on one side with smooth aluminium film. The special adhesive is then coated to the metallised surface to provide a bright silver tape, the total thickness of which is 0·002 in. It has a tensile strength of 20 lb. per in. of width and is said to have good ageing properties and resistance to shrinkage or creep after application. Industrial Tapes Ltd., 19-23 Featherstone Street, London, E.C.1.

EMD 2788 for further information

Casting Resin

A new solid casting resin, Epikote 1040, has been added to the available range of epoxy resins used in the engineering industry. It is intended for use with a new curing agent, called Epikure EPA, and has been developed specially for the production of large castings and for the encapsulation and potting of large electrical components. The cured resin is said to have excellent chemical, electrical and thermal shock-resistant properties. Shell Chemical Co., 170 Piccadilly, London, W.1.

EMD 2789 for further information

Sound Insulation

A new method of sound-deadening light-gauge sheet metal has been evolved. Called Dedshete, it is manufactured in flat sheet and is claimed to impart a high rate of sound "decay" and to ensure efficient suppression of drumming and "tinniness" in sheet metal fabrications. The material is self-adhering to any reasonably clean surface and even to stock-oiled sheet; it is simply placed on the metal and stoved for 5 min. at 150 deg. C., during which time it moulds itself to any contour. Supra Chemicals & Paints Ltd., Hainge Road, Tividale, Tipton, Staffs.

EMD 2790 for further information

Conducting Cement

A heat-conducting cement, called Konduct, is said to have now completed tests and to be available for application to pipelines, pumps, valves and vessels, thereby eliminating the expense of jacketing. It can be applied quickly and easily, and without skilled labour.

The material was developed for use in heat-transfer problems in chemical engineering, but it is thought to have a variety of applications in other branches of engineering. One of its main functions is said to be to increase the heat-transfer contact area between the heating system (whether steam or electrical) and the part to be heated. The cement is recommended for use satisfactorily at temperatures from sub-zero to a maximum of 400 deg. C. John Lord & Son, Wellington Cement Works, Bury, Lancs.

EMD 2791 for further information

Synthetic Enamel

Carltonian hammer-finish enamel is said to have all the usual properties of a high-quality machinery enamel, giving resistance to oil, petrol and heat, mild acids and alkalis, and weathering. The enamel dries, dust-free, in 30 min. and can be handled in about 4 hr., although it does not become very hard until the next day. This drying process may be hastened by mild stoving treatment. It may be applied directly on to bare metal or any other surface by spraying with a pressure of 50 p.s.i. It is available in seventeen colours. Wareing Bros. & Co. Ltd., Calton Street Works, Bolton, Lancs.

EMD 2792 for further information

Thread Jointing

A material recently introduced with the name of Thredseal is intended for making pipe joints for a variety of uses. It is manufactured from p.t.f.e. and is supplied in spools loaded with 480 in. of tape of ½ in. width. In use, a sufficient

length of tape is cut from the roll and wrapped round the thread, allowing for an overlap of about ½ in. and the thread can then be screwed home. It can be used on threads formed in plastics, aluminium, stainless steel or any other material in which threaded connections are formed. It is claimed to be efficient even on imperfectly-formed threads and, because of its self-lubricating qualities, it is said to eliminate galling and seizing, and that connections can be drawn up to a greater degree of tightness than with conventional sealing substances.

The material does not harden, and it is said that joints can easily be broken down after long periods of time. It can be used to seal against pressures of many thousands of p.s.i., and temperatures of −130 to +200 deg. C. (−200 to +500 deg. F.). The tape is equally capable of being used for aggressive fluids such as corrosive chemicals, caustics, hydraulic fluids, aromatic fuels, etc. Crane Packing Ltd., Slough, Bucks.

EMD 2793 for further information

Temperature Indicators

A method of determining temperature by means of pellets or marks which are applied to the surface being heated is now being introduced in this country under the name of Thermomelt. They are said to be accurate to within ±1 per cent and to be available in over sixty different temperature calibrations from 45-1,090 deg. C.

The system may be used in any of three forms. With the Thermomelt Stik, the surface is marked and the mark becomes dull and chalky when the prescribed temperature is reached. A second method is to use the material in liquid form, this being brushed on in a thin coating. The third form is of pellets which start to melt when the desired temperature has been reached. A. Levermore & Co. Ltd., Kenley Park House, Kenley, Surrey.

EMD 2794 for further information

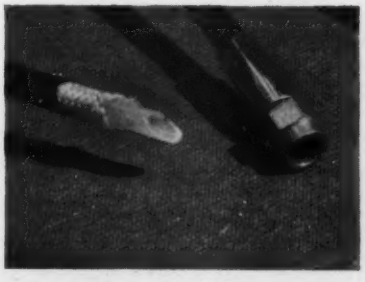
Gel Coat System

A new pre-mixed gel coat system has recently been announced which is based on high-quality general-purpose polyester resins. It is called DSR. 19142, and it is said to avoid the time and money wasted in making small quantities of gel coat mixes, and to eliminate having to dilute thixotropic concentrates. It possesses a degree of thixotropy which ensures that, when applied in suitable thickness, the gel coat will not drain from vertical or steeply inclined surfaces. The new system is said to have been specially designed to combine maximum ease of application with minimum risk of air bubble trapping and subsequent pin-holing. It allows the production of smooth, even gel coats which show good wear, weather, chemical and solvent resistance. Bakelite Ltd., 12-18 Grosvenor Gardens, London, S.W.1.

EMD 2795 for further information

Nylon Hose

High-pressure nylon flexible hose has recently been added to an existing range of nylon pipes. It is said to be ideal for a wide range of hydraulic and pneumatic applications, is supplied with re-usable end fittings and is available in bore sizes ¼, ¼, ⅜ and ½ in. with burst pressure ranging from 11,000 to 7,000 p.s.i., accord-



ing to bore size. Flexing properties for the hose are said to be high, minimum bend radii being 1¾ in. for ¼-in. bore, 3 in. for ⅜-in. bore, 4 in. for ½-in. bore and 5 in. for ¾-in. bore.

In construction, it comprises an inner core of nylon tube, braided with high-tenacity polyester fibre and having an outer sheath of flexible nylon. Tecalemit Ltd., Plymouth, Devon.

EMD 2796 for further information

Men with a lot of liquids to handle know that with ENSECOTE size is no obstacle. Full ENSECOTE protection can now be applied economically to almost any size of tank. For stoving, we have one of the largest furnaces in the country—it's all part and parcel of our major development programme. We can also of course make and erect the tanks—*any* kind of tanks, including fibre glass, P.V.C. and polythene—often saving you time and money.

ENSECOTE linings protect almost anything you can put into a tank. They are easily cleaned and sterilized, completely odourless and tasteless, and will add years to a tank's life.

ENSECOTE *Lithcote* PLASTIC LININGS

For literature and technical advice write to: NEWTON CHAMBERS & CO. LTD., THORNCLIFFE, SHEFFIELD, ENGLAND

Agents in Belgium, France and Holland: FOURS LECOCQ ET ATELIERS DE TRAZEGNIES REUNIS, S.A., TRAZEGNIES, BELGIUM

Electric Motors

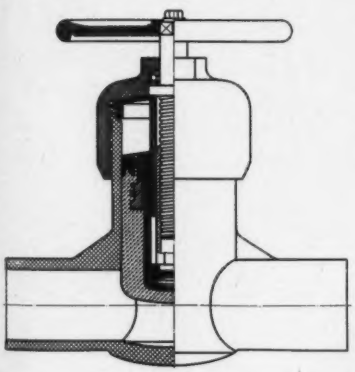
The range of new KN-D electric motors has now been extended from 7½ h.p. to 40 h.p. at 1,500 r.p.m.

These totally-enclosed, fan-cooled machines, now available from stock, are said to comply electrically with B.S. 2613: 1957 and are dimensionally in accordance with draft B.S. (A(ELE)1629). This makes them interchangeable, rating for rating, with A.E.I. drip-proof motors, type KN-C, built in accordance with B.S. 2960: 1958. Type KN-D motors have Class "E" insulation with 65 deg. C. temperature rise. The use of improved insulation has made it possible to offer a motor of smaller dimensions to replace the earlier machine with Class "A" insulation and 55 deg. C. temperature rise. A.E.I. Ltd., Rugby.

EMD 2797 for further information

Plastics Stop Valves

A range of valves manufactured from plastics now available in this country features a new method of sealing which is claimed to be absolutely dependable. By turning a handwheel, a soft rubber cup is forced to the bottom of the plunger passage and then compressed. A lipped packing on the upper part of the shut-off body prevents the medium handled from coming into contact with the stem or from finding its way out of the valve.



The stem is located in two telescopic sleeves which slide inside each other. This arrangement also prevents ingress of the medium. The outer telescopic sleeve acts simultaneously as a pressure tube in the plunger. It reinforces the soft rubber cup from within.

The valve is said to be unaffected by foreign matter in the pipeline, such as sand and welding globules, etc., and the straight-through design with no reduction in the cross-sectional area of passage is claimed to eliminate pressure loss. A variety of materials of construction, for the various parts of the valve, are available for use with different liquids. Goodburn Plastics Ltd., Arundel Road, Trading Estate, Uxbridge.

EMD 2798 for further information

Flexible Bands

A simple method of bunching cables and for securing bundled goods is provided by a range of polythene cable bands. They would appear also to be suitable for bundled coils of wire, etc. Agro Electrical Co. Ltd., National House, 60-66 Wardour Street, London, W.1.

EMD 2799 for further information

Miniature Indicator Lamps

A new round-end glow lamp uses a blown bulb to achieve improved end-on appearance and viewing, when compared with previous types. The new lamp is available in both standard brightness or high brightness. The pressed seal construction allows flexing of the lead wires during assembly operations without fear of lead or seal breakage. The lamp's ¼-in. length is designed to conserve space behind the panel.

The round-end design enables the glowing electrodes to be placed closer to the end of the lamp, and it is said that a brighter and more uniform illumination on any plastics facing or colour cap used in front of the lamp is thus made possible. International General Electric Co. of New York Ltd., Lincoln House, 296-302 High Holborn, London, W.C.1.

EMD 2800 for further information

Solenoid-operated Air Valves

Considerable advantages are claimed for a new range of air control valves. The solenoid is of continuously-rated high-duty pattern and is provided with shock mountings in both directions, tool steel pads to plungers, silicon grain oriented steel laminations wound with Lewmex and insulated with varnished glass fibres and with guides of beryllium copper. The solenoid is claimed to give complete reliability even under very rapid cycling at high temperature, or under "hold-on" conditions.

The valve is directly-operated and not through a pilot orifice, and air flows at 35 c.f.m. may be obtained without using the valve to pilot-operate a larger valve. Where it is used as a pilot valve, the high air flow means that very remote mounting is quite permissible. The valve is of the co-axial poppet type and is said to be easy to service. Provision is made for either foot or side mounting. Air Automation, 26 Sharrocks Street, Wolverhampton.

EMD 2801 for further information

Pump and Ram Unit

A new hydraulic unit, model 4000, consists of a two-speed double-acting pump, with built-in relief valve, integrally fitted to a trunnion-ended cylinder. The pump is operated by a 30-in.-long hand lever, which provides a working pressure to the cylinder of 1,500 p.s.i. The oil displacement is 0·7 cu. in. The ram is available in a range from 1,100-4,400 lb.

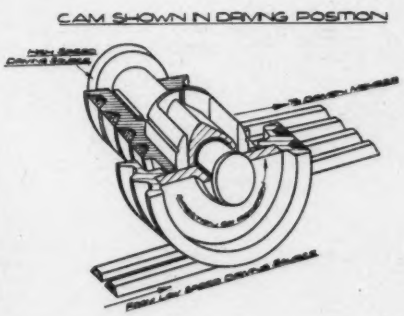
The pump-ram unit would appear to be particularly suited to the design of simple fork trucks, lifting tables and for making up simple presses for special purposes. Linford Engineering Co. Ltd., Baker Street, Birmingham, 11.

EMD 2802 for further information

Clutch/Free-wheel Unit

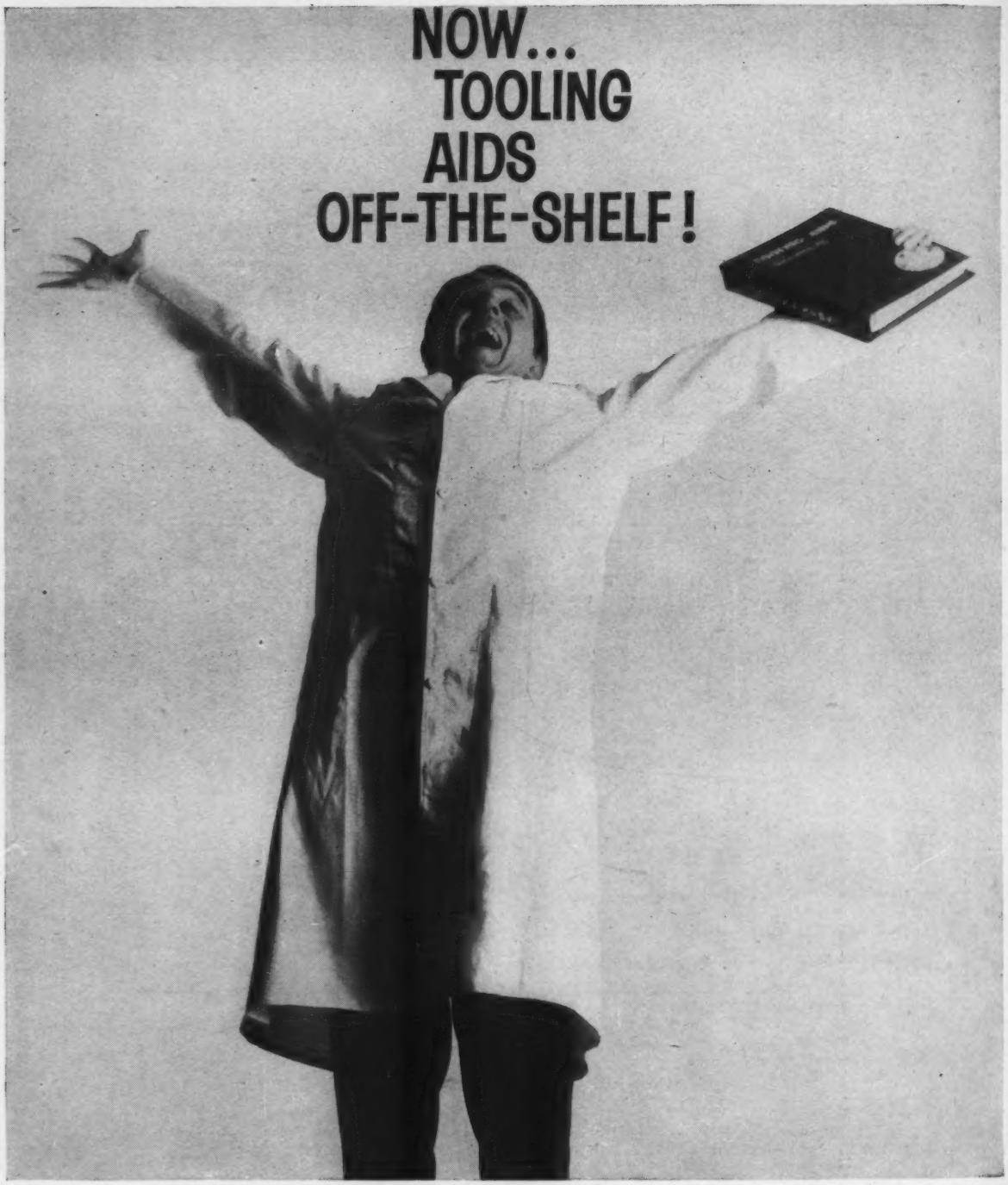
The accompanying sectional drawing illustrates the working principle of a unit developed as a means for transmitting a rotary drive to a driven apparatus from the selected one of two independent driving sources adapted to drive at different speeds. It is also said to be suitable for use as a clutch, overdrive or free-wheel.

An outer rotary member is connected to the faster one of the driving sources and is mounted concentrically about a rotary inner member connected to the other and slower driving member. Coupling means is interposed between the inner and outer member, which is acted upon when the inner member is driven, thus transmitting the drive to the outer member. Conversely, when the outer member is driven, the coupling means is rendered ineffective, thus allowing the outer member to rotate freely about the inner member.



The inner member comprises a cam located between a pair of diametrically-opposed shoes, which constitute the coupling means. This cam is so shaped that its periphery presents two diametrically-opposed straight portions which can become disposed parallel to straight inner faces of the shoes to allow the shoes to retract inwards out of contact with the outer member. In this position the outer member is free to rotate free-wheel fashion without turning the inner member. R. G. Whitaker Ltd., Portland Road, Kingston-on-Thames, Surrey.

EMD 2803 for further information



Yes, this is the way Woodside supplies them. What's more, you can choose *all* your tooling aids from the Woodside Tooling Aids Catalogue as you sit at your desk. Woodside off-the-shelf service means that the tooling aids you need are already made, just waiting to be despatched, so you get extra quick delivery. Quality is the highest attainable . . cost surprisingly low. And just one other thing. If you haven't got your Woodside Tooling Aids Catalogue yet, now's the time to ask for it.

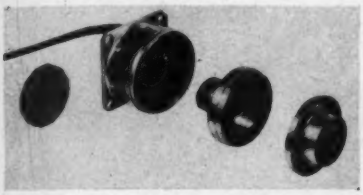
W.D.S tooling aids for industry

WOODSIDE DIE SINKING COMPANY LIMITED

Woodside Die Sinking Company Limited, Aire Vale Works, Newlay, Leeds 13. A KCC Company
Telephone No. Horsforth 4251/4 Telegrams: Wooddie. Leeds. Telex No. 55185

Electro-magnetic Clutch

A miniature electro-magnetic unit, the S.F.100, only 1¼ in. in diameter, has been added to the Warner range. It has been designed to transmit a maximum static torque of 2 lb./in. It is rated at only 6 watts and has a response time of a few milli-seconds. The new miniature clutch (or clutch coupling), which can achieve a maximum speed of 15,000 r.p.m., is stated to be particularly



suitable for use in control mechanisms on light instrument drives, computers and servo mechanisms.

The unit consists of one stationary and two rotating parts. The stationary member is the field which contains the coil. When this is energised, flux flows from the field to the rotor, which attracts the armature, allowing the driving member to be coupled to the driven member. The armature is mounted on a splined hub, the hub being attached to either the driving or driven shaft, thus allowing the armature to move axially for automatic compensation of wear and effective release when the clutch is de-energised. Westool Ltd., St. Helen's Auckland, Co. Durham.

EMD 2804 for further information

Plastics Expansion Unit

The latest addition to the range of available expansion units is a single-operation version. It is available for use with plastics pipe installations from ½ in. nominal pipe size upwards, and allowance of expansion from 2-6 in. can be obtained.

The single units can be supplied with either sockets or flanges as required. Barflo Ltd., 56 Cavendish Place, Eastbourne.

EMD 2805 for further information

Precision Plastics Balls

A wide range of plastics balls, in sizes from $\frac{5}{32}$-2½ in. diameter, are now available in a large number of materials. These include three grades of nylon, polythene, cast phenolic resin, methyl methacrylate and p.t.f.e. Accuracy is of the order of ±0·002 in. for diameter and 0·005 in. for sphericity in most cases, in some cases being even closer.

The balls are suitable for a large number of applications such as check valves, ball bearings, flour milling, indicators, ball mills, etc. Insley Industrial Supply Co. Ltd., 21/22 Poland Street, London, W.1.

EMD 2806 for further information

Low Inertia Motors

The 953-956 series of cylindrical low inertia motors have been developed as an instrument which has an electrical performance comparable to the 900-908 series open type, but having the obvious advantages of cylindrical construction, with respect to fitting, appearance and ingress of foreign matter. They are permanent-magnet d.c. motors in which practically all factors likely to affect the linearity of the voltage/speed curve have been eliminated. The accuracy achieved is such that they are claimed to be suitable for integrating minute voltages on a time basis. By using a suitable transducer, temperature difference, or any other quantity, can be converted into a voltage signal which then enables the motor to integrate this figure over time. Such motors can be used in instrument-type servomechanisms for driving light loads, for operating mechanical counters performing integration, or as small power generators. The sensitivity claimed is such that it will operate directly off a photocell or thermocouple. The motors are available with a wide range of gearboxes with ratios from 80:1 to 3:1. Electro Methods Ltd., Stevenage, Herts.

EMD 2807 for further information

Split Mechanical Seal

Sectaflex mechanical seals have been developed for use on all types of rotary shaft equipment—pumps, compressors, agitators, mixers, etc., for pressures up to 100 p.s.i.g. and temperatures up to 300 deg. F. and where a slight leakage of only a few c.c. per hour would be permissible.

The Sectaflex seal is a face-type mechanical seal in which sealing action is obtained by arranging for intimate contact between the rubbing surfaces of two assemblies, one of which is held stationary while the other rotates with the shaft. As the components are subjected to wear, they are each divided into two halves and assembled together in accurate alignment with the assistance of a solid locating ring. A third component, a flexible O-ring designed to prevent leakage along the shaft, is also split for ease of replacement. A variant of the basic design is also available in which provision is made for a positive circulation of the product being handled past the rubbing faces.

Successive trials are said to have proved the efficiency of the seal for handling a wide range of fluids. A considerable

advantage claimed lies in the ease of maintenance and that shafts do not become worn. Flexibox Ltd., Nash Road, Trafford Park, Manchester, 17.

EMD 2808 for further information

Sub-miniature Relay

A new plug-in, sub-miniature, sealed relay, series 336, is announced. Its dimensions are 1·03 in. high, inclusive of pins, 0·78 in. wide and 0·35 in. deep. The gold-plated silver, double-pole, changeover contact arrangement is claimed to be capable of switching 2 amps resistive load at 28 volts d.c. or 110 volts a.c. By virtue of its rugged construction and the rotary balanced armature, the relay is said to have good performance characteristics under vibration in any plane between 30 and 2,000 c/s. It is rated for operation in ambient temperatures between −65 and +100 deg. C. Operating on 0·35 watts it will close in 3 ms. and release in 2 ms.

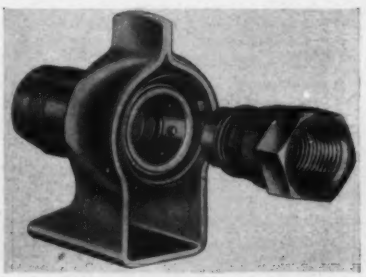
Evacuated under heat and dry nitrogen filled prior to sealing, this relay can be provided, in addition to the plug-in version, with a variety of mountings including hook terminals. Magnetic Devices Ltd., Newmarket, Suffolk.

EMD 2809 for further information

Quick-release Sealing Coupling

A new quick-release self-sealing coupling for use in all hydraulic feed lines of up to 3,000 p.s.i. working pressure is now on the market. It is being manufactured with either British standard or American threads, and, by the use of adaptors supplied as required, is available in two sizes, namely ¼ and ½ in.

The coupling is designed for use on both general industrial and agricultural equipment, and for the latter type of application a mounting bracket is supplied which enables the coupling to be fixed to a tractor or some other towing vehicle. When so installed, one half of the coupling is held by the bracket but the other half is free to disengage automatic-



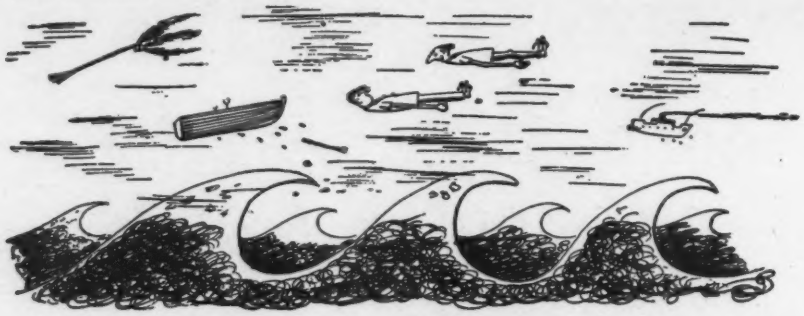
ally should an unexpected pull be applied to the hose line. In this way, both hose and coupling are safeguarded from accidental damage. Used with or without the "breakaway" bracket, the coupling is self-sealing on disconnection.

The coupling consists of two halves, each using a spring-loaded poppet sealing valve and a spring-loaded thimble ring for quick attachment. When connected, the halves of the coupling are sealed with a rubber sealing ring and held in position by a series of hardened steel balls working in tapered location holes.

Negligible restriction to the flow of hydraulic fluid through the coupling is claimed. Super Oil Seals & Gaskets Ltd., Kings Norton, Birmingham.

EMD 2810 for further information

EMD 2722 for further information



This is nothing to what goes on inside a —

BULLOWS NOPUMP

SPRAY BOOTH

ALMOST ENTIRELY ELIMINATES MAINTENANCE

NO PUMP
NO FILTERS
NO PIPES
NO NOZZLES

In this new type of Water-Wash Spray Booth the exhaust air travels at very high velocity over the water surface entraining water. The air/water mixture, moving through controlled changes of direction, provides the scrubbing action.

★ **A NEW PATENTED PROCESS OF WATER TREATMENT...** substantially increases the efficiency of these Booths.

NO CLEANING OUT AFTER 1 YEAR'S CONTINUOUS DOUBLE-SHIFT WORK AT

Massey-Ferguson
(UNITED KINGDOM) LTD.

STRETFORD · MANCHESTER

This Booth was started up on production on 1st March, 1959, and has operated two nine-hour shifts on continuous painting of agricultural machinery. When last examined, there was an average depth of silt of 6 inches over the entire water tank bottom, an area of 290 sq. feet. A further 4 inches, making 10 inches in all, can be accommodated before cleaning is essential. After 1 year's operation, the fan and ducting were barely discoloured, the only maintenance cost being cleaning the floor inside the booth, routine greasing of bearings and similar preventive maintenance.

VISITS TO FACTORIES WHERE BULLOWS' NOPUMP SPRAY BOOTHS HAVE BEEN INSTALLED CAN BE ARRANGED ON REQUEST. WRITE TODAY FOR FULL DETAILS OF THIS OUTSTANDING BULLOWS' ACHIEVEMENT.

A. BULLOWS & SONS LTD · LONG ST · WALSALL · STAFFS · TEL 5401

DEPOTS AT: 13 SOUTH MOLTON ST., LONDON, W.1. TEL: MAYFAIR 2313
55a BRIDGE ST., MANCHESTER, 3. TEL: BLACKFRIARS 5670
70 GILMOUR ST., GLASGOW, C.5 TEL: SOUTH 2383
61-63 DRURY ST., DUBLIN. TEL: DUBLIN 73188/9

Potentiometer

The range of moulded track potentiometers available has been augmented by a new hermetically sealed type, the XP5. Designed to operate within the temperature range −40 deg. C. to 70 deg. C., the new potentiometer conforms with the Inter-Service Standards for radio components. It is said to withstand severe bumping, vibration and tropical exposure.

The XP5 is entirely moisture-proof. The spindle is sealed with neoprene rings which, seated in channels and lubricated with anti-freeze grease, give a smooth action free of bearing slop. The silver-plated terminals are integrally connected to the resistance element and protrude through sealed ceramic insulators. A neoprene washer fitted to the mounting face provides the panel seal essential for use in sealed equipment.

Resistance extends from 500 ohms to 2·5 megohms (linear or logarithmic). Maximum working voltage across resistance is 500 volts d.c. subject to power rating limitations. Plessey Co. Ltd., Ilford, Essex.

EMD 2811 for further information

Compression Terminals

The Twingrip range of compression terminals is now being made available in a pre-insulated form, from size 0 to size 3 (for conductors from 7/·0076 to 7/·036). Previously, to insulate a terminal involved fitting a sleeve after compression, which, although simple in itself, meant two separate operations. With the introduction of pre-insulated terminals, the joint is compressed and insulated simultaneously.

The ferrule of the terminal is covered with a coloured p.v.c. insulation, corresponding with the colour coding of the compression toolhandle, i.e., green for size 0, red for size 1, blue for size 2 and yellow for size 3. Hellermann Ltd., Crawley, Sussex.

EMD 2812 for further information

Wobble Stick Operator

A wobble stick operator, designated class 9001, type TW-1, has been introduced to form a further extension to the range of oil-tight heavy-duty control units made by the company. This operator will replace any standard Type T push-button operator, and it is actuated by pushing the lever in any direction. Because of the method of operation, the wobble stick is said to be particularly suited for use as an "emergency stop" operator on a pendant-type station where it would be desirable to reach the operator quickly from any direction. Square D Ltd. Cheney Manor, Swindon, Wilts.

EMD 2813 for further information

Hydraulic Control

A new design of hydraulic control now permits the use of any number of valves in the bank either individually or simultaneously without load drop when controlling cylinders at lower than mains operational pressure. This has been achieved by incorporating a check valve of special design in the valve body and positioning it in the pressure line between the valve spools. Specially developed methods of forming the valve ports ensure that this check valve and associated porting are of sufficient capacity to avoid the generation of heat under operational conditions.

This multi-bank valve is said to be very adaptable. Composite banks of valves to provide any specified number of controls can be made up from only three basic units which can be quickly and easily combined to suit particular needs.

The valves are made in a range of sizes with capacities from 15-45 gal./min. at operating pressures up to 2,000 p.s.i. They can be used to advantage in any mobile or stationary hydraulic control system, and are suitable therefore for all types of mechanical handling equipment, coal-mining appliances, earth-moving vehicles and other hydraulically controlled and operated machinery. Joseph Young & Sons Ltd., Kay Street, Bolton, Lancs.

EMD 2814 for further information

Magnetic Transducer

The magnetic transducer, type MA.95, is a coaxial magnetic probe unit primarily intended for the direct measurement of shaft speed where no physical connection to the shaft under test is possible. In operation it is merely necessary to position the transducer close to an ordinary gear wheel or toothed wheel of ferrous material and an output is obtained which can then be counted and indicated on a digital computer. The MA.95 comprises a permanent magnet and associated coil encapsulated in a coaxial housing. Shaped, detachable pole pieces can be supplied to suit various tooth forms and the output is brought to a connector situated at the rear of the unit. No moving parts are involved in the transducer and, as it can be rigidly mounted close to the gear and shaft under test, a high order of reliability in performance is ensured. Racal Instruments Ltd., Western Road, Bracknell, Berks.

EMD 2815 for further information

Speedy Hose Clip

On page 249 of our April issue we described the O-Clip hose clip which was recently introduced. The accompanying photograph, however, illustrated a device known as the Band Clip. The O-Clip is made in sizes from ¼ to 2¼ in., whereas the Band Clip is suitable for all diameters over 2 in. Matchless Machines Ltd., 12 Tottenham Street, Tottenham Court Road, London, W.1.

EMD 2816 for further information

New Publications and Technical Literature

Henry Wiggin & Co. Ltd.: Revised booklet explaining the technique of applying the protective coating of Brightray nickel-chromium heat-resisting alloy to exhaust valves. Thames House, Millbank, London, S.W.1.

EMD 2817

British Cellophane Ltd.: Series of booklets giving properties and uses of five new plastics films based on nylon, polypropylene, plasticised p.v.c., polyvinyl alcohol and polystyrene. Henrietta House, 9 Henrietta Place, London, W.1.

EMD 2818

Imperial Aluminium Co. Ltd. (I.C.I. subsidiary): Illustrated brochure showing range of aluminium extruded and drawn products. P.O. Box 216, Witton, Birmingham, 6.

EMD 2819

Industrial Hydraulics Ltd.: Brochure describing Liquid Seal range of gas-loaded piston separator units covering industrial applications up to 5,000 p.s.i. 101 London Road, Reading, Berks.

EMD 2820

Spembly Ltd.: Leaflets dealing with capacitor discharge welding apparatus and special hot plates. New Road Avenue, Chatham.

EMD 2821

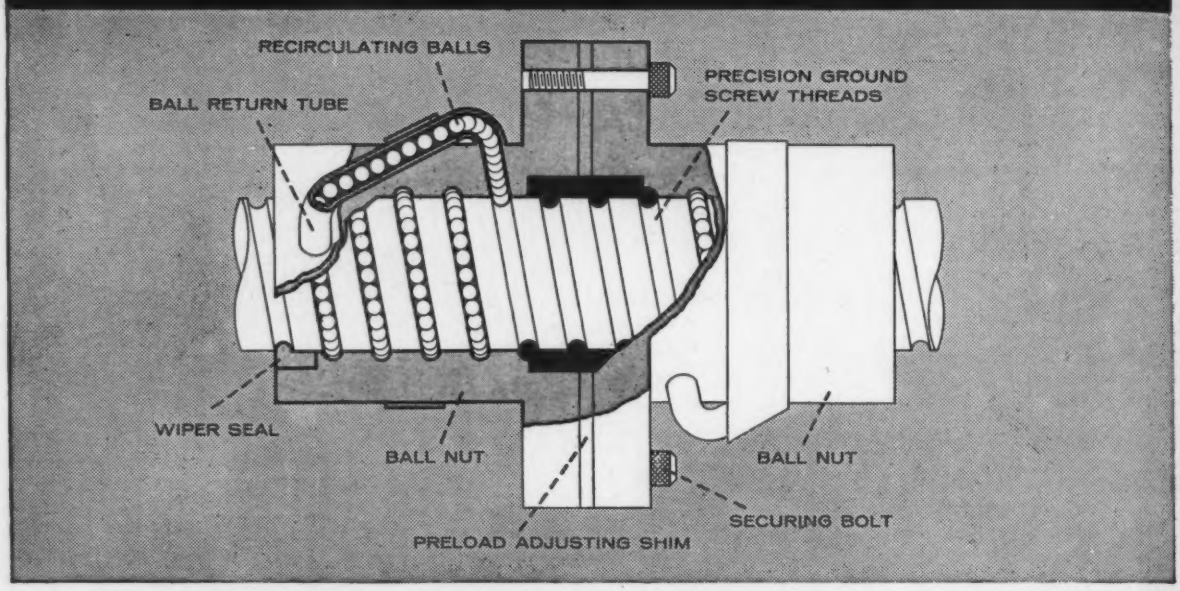
Bakelite Ltd.: Booklet outlining some uses of epoxide resins marketed by the company. 12-18 Grosvenor Gardens, London, S.W.1.

EMD 2822

Zinc Development Assoc.: Booklet listing publications and films that are available on zinc applications and techniques. 34 Berkeley Square, London, W.1.

EMD 2823

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J. B. Starky, Sales Manager (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

News of Industry

The **National Engineering Laboratory** is to hold open days on June 15 and 16 this year. Facilities for sponsored investigations for industry will be on show, as well as results carried out as part of N.E.L.'s general programme of basic and applied research. Invitations will be sent to any organisations with engineering interests.

Shell Chemical Co. is to start production of new polydiene rubbers in the U.K. For many end-uses, say the company, these new rubbers are comparable in performance to top-grade natural rubber and in some respects, such as abrasion resistance and heat build-up, are superior. Limited supplies for evaluation are to be made available soon.

As from the end of April, Deri-Sine pumps and motors will be available from either **Denison-Deri Ltd.** or from **Andrew Fraser & Co. Ltd.** Previously these products were marketed in the U.K. solely by Andrew Fraser.

An exhibition concerned with problems of effluent and water treatment is to be held in London from October 18-21 this year. It is to be run concurrently with a convention on the same subject. Details from the organisers, Thunderbird Enterprises Ltd., 140 Cromwell Road, London, S.W.7.

British Hydrocarbon Chemicals Ltd. are to build three new major plants in Scotland. One will more than double the existing capacity for the production of butadiene, while the other two are for the manufacture of methanol and ethylene dichloride.

The conversion by **Steel, Peech & Tozer** of their Rotherham open-hearth melting shop to an electric-arc melting shop is the subject of a paper to be presented at the annual meeting of the Iron and Steel Institute in London on May 5.

A convention on the role of nylon in industry is being organised by **British Nylon Spinners Ltd.** in London on May 25 and 26.

The establishment of a scientific publications department specialising in the production of international scientific journals is announced by **Heywood & Co.**, publishers of ENGINEERING MATERIALS AND DESIGN. Each will be edited by leading authorities, who will have the assistance of an international editorial advisory board. Main contents will consist of original papers and brief notes of new discoveries in the form of letters to the editor and, where appropriate, short descriptions of technical developments. The first journal, *Cryogenics*, will make its appearance in June.

A new fabrication shop has been added to the Sheffield works of **Keeton, Sons & Co.** Its completion enables the firm to carry through its policy of constructing all future Keetona sheet metalworking machinery to a new modern design in fabricated steel, in preference to cast iron.

Northern Aluminium Co. Ltd., in conjunction with Aluminium Laboratories Ltd., have carried out tests and development work on a new system of M.I.G. consumable electrode welding using self-feeding guns that carry a small spool of wire, instead of a larger spool being located some distance away. This means that the wire, instead of being pushed through distances of perhaps 10 ft., has only to be pushed about 3 in.; thus, a much thinner wire can be used. The system has been used in the U.S.A. for several years and is being marketed in this country as the Rowen-Gun by Rubery Owen & Co. Ltd.

An agreement has been signed between **B.S.A. Tools Ltd.** and **Harford Pumps Ltd.** for the manufacture in the U.K. of the Opio glandless circulating pump which has been previously imported by Harford.

At the invitation of the **Magnesium Industry Council**, the spring meeting of the Magnesium Association of America will be held in the U.K. at the end of May.

A recent exhibition by **Formica Ltd.** demonstrated the rigorous tests which their products, ranging from the domestic grades to laminated resin-bonded material for complex electronic and mechanical applications, undergo to ensure that the inherent properties are maintained over a wide range of environments and working conditions. Each batch of material is subjected to both chemical, electrical and mechanical tests and strict control is exercised during impregnation and curing, thus ensuring uniformity of properties in the finished materials. Products shown included tubing and extruded sections in p.v.c., polystyrene and polythene.

The **Institution of Electrical Engineers** is organising the third International Conference on Medical Electronics which will be held at Olympia from July 21-27.

C.J.R. Electrical & Electronic Developments Ltd. have changed their name to Witton Electronics Ltd. Address is still Bickford Road, Witton, Birmingham, 6.

Shaw Moisture Meters announce a change of address to Rawson Road, Bradford, 1.

A party of four Russians recently visited the **Hoover Ltd.** factory at Perivale. Their visit, part of a British tour, was organised in conjunction with the Production Engineering Research Association which sent a delegation to the U.S.S.R. last year.

Elga Products Ltd. are making available a new mobile exhibition dealing with the deionisation method of providing distilled water for the use of senior members of industrial, research and teaching laboratories. The techniques illustrated are the batch method, multi-column and mixed-bed systems with regeneration *in situ* and the mixed-bed cartridge-type system.

Hanovia lamps division of **Engelhard Industries Ltd.** have taken over the sole agency in the U.K. for Heraeus Quarzschmelze G.m.b.H. of Hanau, West Germany. Heraeus manufacture optical and commercial grades of fused quartz for industrial and laboratory applications.

This Goodbrand instrument measures the bursting strength of paper by the application of hydraulic pressure to a fixed section of the paper. This is one of the tests made to all batches of paper received at Formica Ltd. (See story this page.)

British Insulated Callender's Cables Ltd. announce formation of a new company, **Telcon Metals Ltd.**, which has assumed responsibility for all the activities of the metals division of the Telegraph Construction and Maintenance Co. Ltd. These include Telcon magnetic materials and other special alloys.

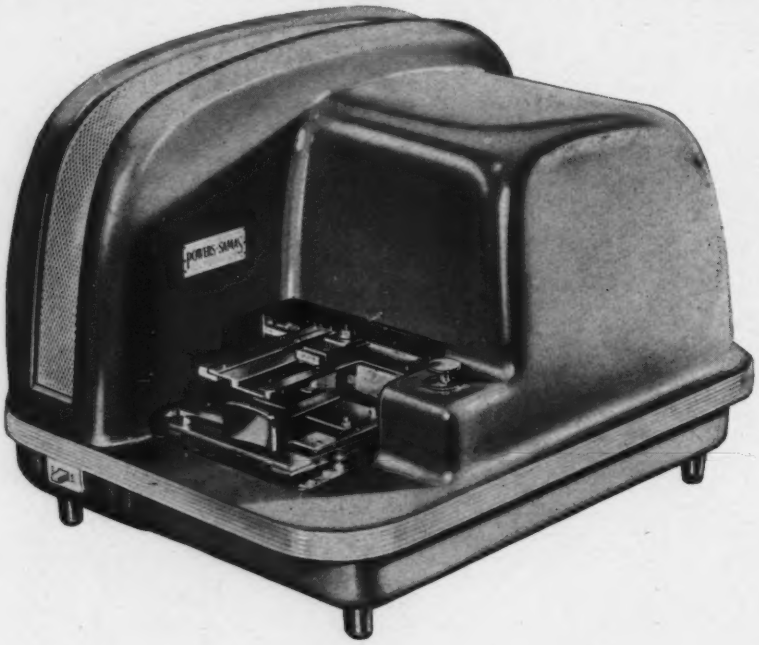
Pantak Ltd. have concluded an agreement with Sierex Ltd. for the marketing and servicing of the Siemens 15 meV industrial betatron. The introduction of this equipment will add to Pantak's range of industrial X-ray equipment.

An important aspect of the use of the betatron is the use of an enlargement technique, which is said to give an extremely high flaw sensitivity. Enlargements of up to four times normal size are claimed possible, enabling the detection of very fine flaws.

Head Wrightson Processes Ltd. have formed an industrial furnace division to meet expanding operations in the petroleum and chemical industries.

EMD 2724 for further information

Design success for I.C.T



Cellobond Polyester/Glass

adds strength and style

Re-styled by Mark Schejbel, one of Britain's leading industrial designers, the I.C.T punched card reproducer has its cover and base moulded in Cellobond Polyester/Glass. Result: an outstanding design—a more efficient machine. The Cellobond mouldings used are lighter, stronger . . . they replace space-wasting angles with stress-resisting curvatures . . . and they cost two-thirds less than the metal components previously used.

Potential users please note:

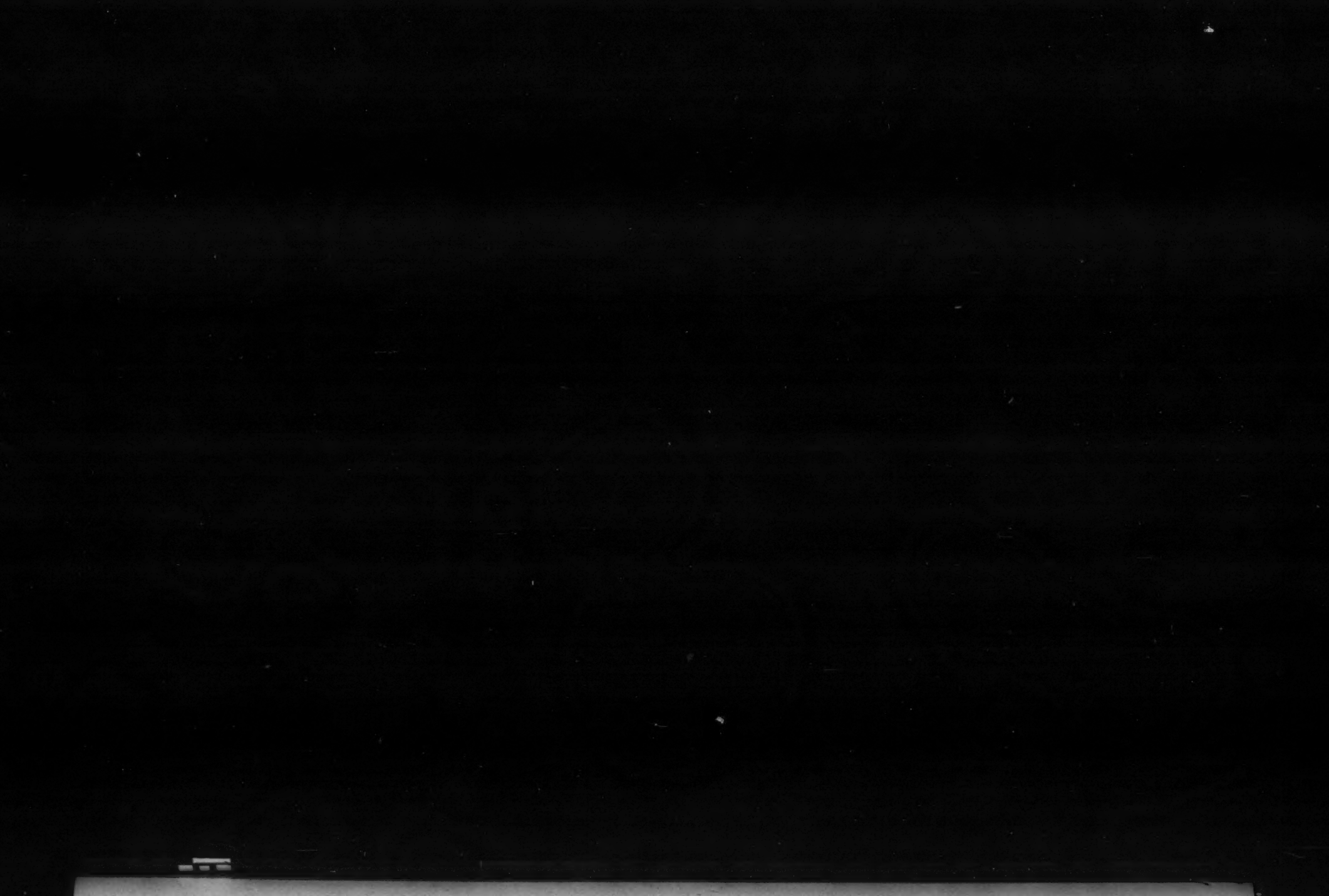
* BRP can put you in touch with specialists in Cellobond Polyester/Glass construction.
* On-the-spot assistance is available to all Cellobond users.
* The process is discussed in BRP Booklet No. 115. Please write for a copy.

Cellobond Polyester/Glass saves Time and Labour

The new design, made possible by Cellobond Polyester/Glass, simplifies assembly of the machine and cuts production costs. Adaptable and dependable, Cellobond Polyester/Glass frees designers from the limitations of conventional materials, enabling manufacturers to combine form and function elegantly, reliably and more profitably.

Cellobond is a reg'd trade mark

British Resin Products Ltd A COMPANY IN THE DISTILLERS PLASTICS GROUP BRP

SALES AND TECHNICAL SERVICE DEVONSHIRE HOUSE PICCADILLY LONDON W1 HYDE PARK 0151

Distillers Plastics Serve Everyman